APPENDIX M

Intake Effects Assessment

Prepared by Tenera Environmental, February 2010

Poseidon Resources
Huntington Beach Desalination Facility

Entrainment and Impingement Effects from Operation of the Huntington Beach Desalination Facility in Standalone Mode

Final Report

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Executive Summary

Poseidon Resources Corporation proposes to build and operate the Huntington Beach Desalination Facility (HBDF) adjacent to the AES Huntington Beach Generating Station (HBGS). The facility will convert a fraction of HBGS's condenser cooling seawater discharge into fresh drinking water using a reverse osmosis desalination process. Source water for this facility will be taken from the existing HBGS condenser cooling-seawater discharge system, which is permitted to circulate up to 507 million gallons per day (mgd) of seawater for cooling purposes. After the seawater passes through the HBGS's condensers, the desalination facility will withdraw approximately 100 mgd from the cooling water stream and produce 50 mgd of high-quality potable drinking water for use by residents and businesses in Orange County. The remaining 50 mgd becomes concentrated seawater, which will be discharged into the cooling water discharge system downstream of the desalination facility's intake point where it will be diluted with up to 407 mgd of HBGS's condenser cooling flow prior to being discharged back into the Pacific Ocean.

However, if in the future, the HBGS were to cease the use of once-through cooling, or if the HBGS were to permanently alter their cooling water system's historical operations and reduce its seawater intake to less than 152 mgd, the proposed seawater desalination facility would intake water directly from the Pacific Ocean via the existing HBGS intake pipe in order to bring in 152 mgd. The desalination facility would use 52 mgd of the 152 mgd for diluting the discharged concentrated seawater.

Recent studies on the effects of the HBGS cooling water intake system on the ocean environment were conducted in connection with a re-powering project certified by the California Energy Commission (CEC). An Impingement Mortality and Entrainment (IM&E) Characterization Study (MBC and Tenera Environmental 2005) was submitted to the Santa Ana Regional Water Quality Control Board as part of the HBGS NPDES permit application that required compliance with provisions of the 316(b) Phase II regulations of the Clean Water Act. The sampling data collected in this 2003–2004 IM&E study were included as part of the HBDF EIR submittal to the City of Huntington Beach. That report (Tenera Environmental 2004) investigated the potential for the HBDF to increase HBGS entrainment mortality and assessed the significance of intake effects on the source water.

To further determine the potential effects of the proposed HBDF on larval fishes and shellfishes, data from the 2003–2004 study have been re-analyzed in this report using a proposed intake volume of 152 mgd, the volume of seawater supplied by two of the generating station's eight main circulating water pumps and the minimum volume for full independent operation of the desalination facility. A daily intake flow of 507 mgd used in all of the impact assessment calculations from the original study for the HBGS cooling water system was reduced to the proposed 152 mgd flow to model impacts from the desalination facility. This report was designed to address the following questions for the HBDF potentially operating in a standalone mode:

- What are the composition and abundance of species that could be impinged (organisms trapped on the intake screening systems) due to the operation of the effect of the HBDF feedwater intake of 152 mgd?
- What are the composition and abundance of species that could be entrained (planktonic larvae pumped through the cooling water system) by the HBDF feedwater intake of 152 mgd?
- How might losses due to feedwater impingement and entrainment affect the source water populations of fishes and invertebrates in the Southern California Bight, and are such losses ecologically or economically significant?

Overview of Findings

Impingement

The total numbers of fishes collected during each survey in the 2003–2004 study were used to estimate losses based on an assumed linear relationship between flow rate and impingement. The impingement measurements and corresponding flows for each sampling date were analyzed using regression to obtain estimates of coefficients describing the relationship. These coefficients were then used to recalculate an estimate of the total annual impingement. The main conclusions of the analysis were:

- ***The proposed operation of the HBGS intake system for the HBDF would result in an estimated average daily impingement of 13 fishes weighing 0.3 kg (0.7 lb).*** The most abundant species impinged were queenfish (81%), northern anchovy (6%), white croaker (3%), and shiner perch (2%) (**Table ES-1**). All of the other species comprised 1% or less of the total estimated annual impingement. The existing data and results from previous studies on the effectiveness of the intake velocity cap indicate that impingement may be even lower at the low flows projected for the HBDF than would be predicted based on the proportional relationship of impingement to flow.

- ***Impacts to fish populations caused by impingement under HBDF standalone operations would not be significant, either ecologically or economically.*** Although there were no source population estimates available for impinged species to evaluate the losses on a population level, a very conservative assumption was used to estimate that the total annual ex-vessel value of all impingement losses would amount to approximately $526. The low biomass impinged, the low value of the total impingement, and the fact that no threatened or endangered species were collected during the sampling indicated that projected impingement losses would be insignificant.

- ***Impacts to shellfish populations caused by HBDF impingement would also be ecologically and economically insignificant.*** The estimated average daily impingement rate for shellfish was approximately 7 individuals weighing 0.1 kg (0.2 lb). The most abundant species were yellow crab (41%), graceful crab (19%), and Pacific rock crab (13%). Other shellfishes in impingement samples included shrimps, octopus, spiny lobster, and market squid. It was determined that most of the impingement of shellfishes probably occurs from organisms living within the CWIS. As a result there is little potential for impingement of shellfishes and other invertebrates to affect source water populations of these species.

Table ES-1. Estimated annual fish impingement abundance and biomass adjusted proportionally for maximum HBDF desalination flow (152 mgd).

Species	Common Name	Estimated Abundance	Estimated Biomass (kg)	Percent of Total Abund.	Percent of Total Biomass
Seriphus politus	queenfish	3,939	22.271	81.2	18.9
Engraulis mordax	northern anchovy	298	1.944	6.1	1.7
Genyonemus lineatus	white croaker	127	1.497	2.6	1.3
Cymatogaster aggregata	shiner perch	85	0.808	1.7	0.7
Peprilus simillimus	Pacific pompano	53	0.848	1.1	0.7
Porichthys myriaster	specklefin midshipman	52	5.643	1.1	4.8
Phanerodon furcatus	white seaperch	36	0.196	0.7	0.2
Sardinops sagax	Pacific sardine	33	1.705	0.7	1.5
Urobatis halleri	round stingray	26	8.538	0.5	7.3
Leuresthes tenuis	California grunion	17	0.074	0.3	<0.1
26 other species		187	74.055	4.0	62.8
	Total	**4,853**	**117.579**	**100**	**100**
	Number of Species	**36**			

Entrainment

Potential impacts to fish and invertebrate populations caused by the entrainment of planktonic larvae can only be assessed indirectly through modeling. The assessment included the most abundant fish taxa (target taxa) that together comprised 90% of the total estimated larvae entrained annually. Entrainment impacts were assessed, when sufficient information was available, using two demographic models, Adult Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*), which translate larval entrainment estimates into adult losses. A third modeling approach, the Empirical Transport Model (*ETM*), compared the numbers of larvae entrained with the numbers of larvae at risk of entrainment in the source waters to obtain an estimate of the proportional mortality caused by entrainment. Summarized results from these modeling estimates are presented in **Table ES-2**. Entrainment impacts were additive with the direct losses identified from the impingement sampling.

The results of the entrainment portion of the study were as follows:

- ***The nearshore ocean environment off of HBGS supports a diverse assemblage of larval fishes and shellfishes, but is less diverse than coastal areas that are in proximity to rocky reefs.*** A total of 53 larval fish species (including combined taxa categories) was collected during 44 entrainment surveys completed in 2003–2004. Ten taxa, characteristic of nearshore sandy and open water environments, comprised approximately 90% of the total larvae collected: gobies, spotfin croaker, northern anchovy, queenfish, white croaker, unidentified croakers, salema, combtooth blennies, black croaker, and diamond turbot. Of these ten abundant fish taxa entrained at HBGS, seven have some commercial or recreational fishery value.

- ***The most abundant taxon based on estimated total annual entrainment of larval fishes (33%) was CIQ gobies—a small, bottom-dwelling type of fish that is common in bays and lagoons.*** Nearby adult populations are concentrated in localized habitats, such as Alamitos Bay, Anaheim Bay, and Talbert Marsh, and their larvae are dispersed in these environs and transported out into coastal waters by tidal flushing and prevailing currents. These larvae would experience much higher rates of natural mortality than larvae that are retained in shallow bay habitats where they sustain resident adult populations.

- ***The life history of species in the community must be considered when discussing potential effects to fish and shellfish populations due to HBDF operation.*** Although the study focused on species that produce planktonic larvae and are therefore potentially affected by entrainment, it is important to note that many common species have early life stages that are not susceptible. For example, live-bearers, such as the several species of surfperches, sharks, and rays common to the area, produce young that are fully developed juveniles too large to be affected by entrainment.

- ***The proportion of larvae potentially entrained through the HBDF ranged from 0.02–0.33% of the source water populations of approximately 115 billion larvae, based on the ETM model results.*** Because of larval transport in ocean currents, larvae could potentially occur over a coastline distance of up to 100 km (60 mi). However, these levels of additional mortality would be considered very low, especially when the populations of these species extend over a much larger geographic range than the extrapolated source water bodies.

- ***Potential losses of adult fishes, based on demographic modeling for several of the more abundantly entrained species, ranged from a low of 4 individuals per year for California halibut (0.03% of alongshore source water population) to a high of over 350,000 per year for northern anchovy (0.24% of alongshore source water population).*** Sufficient life history information was obtained from the scientific literature to model impacts on six of the eleven taxa that were analyzed in greater detail. Demographic modeling (*FH*) of CIQ goby larval entrainment estimates showed potential losses of approximately 85,000 adults per year (0.21% of source water population). This was a conservative estimate because the most accurate larval survival rates available for the *FH* model were based on estuarine areas, and actual survival rates in open coastal waters were probably much lower.

Impact Assessment Conclusions

The proposed operation of the HBGS intake system for the HBDF would result in an estimated daily impingement of 13 fishes weighing a total of 0.3 kg (0.7 lb), equating to an annual estimated impingement of 4,853 fishes weighing 117.6 kg (259 lb). Several approaches were used for estimating the results which indicated that the average daily totals could vary from 7 to 22 fish, resulting in an annual total of approximately 2, 500 to 8,000 fishes. The existing data and results from previous studies on the effectiveness of the intake velocity cap (Thomas et al. 1980c) indicate that impingement may be lower at the low flows projected for the HBDF than would be predicted based on the proportional relationship of impingement to flow. In addition, no state or federal threatened or endangered species were collected during the impingement sampling. Low impingement rates and the lack of impinged listed species indicate that the impacts of impingement under HBDF stand alone operations would be insignificant.

Larval entrainment losses due to operation of the HBDF are projected to affect only a small fraction of the larvae (0.02–0.33% of the source water populations of approximately 115 billion larval fishes) at risk to HBDF entrainment, that occur within the source waters of the Southern California Bight. One of the summary conclusions in the original report on the IM&E studies at HBGS were that estimated levels of P_M were much less than the estimates from other coastal power plants in California. This was attributed to the location of the plant along a fairly homogeneous stretch of coastline dominated by sandy habitat that provides less diverse habitat for fishes than rocky coastal or estuarine areas where some of the other plants are located. The coastal currents in the vicinity of the HBGS spread any effects of the entrainment losses over tens of kilometers of coastline limiting any effects to the populations. In addition, no state or federal threatened or endangered species were collected during the entrainment sampling. The small fraction of source water larvae entrained and the lack of entrained listed species indicates that the impacts of entrainment under HBDF stand alone operations would be insignificant.

One approach to assess the significance of potential losses is to translate them to direct economic impacts on fisheries. Catch data from Los Angeles ports for 2004–2008 were used to estimate the ex-vessel commercial fishery value of entrainment losses for northern anchovy, white croaker, California halibut, and rock crabs. The projected revenue losses amounted to less than $500 annually for these species combined. When the total impingement biomass from all species was assigned a very conservative value for one of the most highly prized fishery species, California halibut, it was estimated that equivalent commercial fishery losses due to impingement would be less than $600 annually. Potential losses to recreational fisheries could not be readily converted to a dollar value, but the small fractions of fishery species in the source water that would be affected by impingement and entrainment at the HBDF suggest that such losses would be insignificant.

Table ES-2. Summary of entrainment modeling estimates on target taxa based on the three modeling techniques (*FH, AEL,* and *ETM* [P_M]). The *FH* model estimates breeding adult females, therefore this estimate is multiplied by two for comparison with the *AEL* model that estimates numbers of adults, irrespective of sex. The comparison assumes a 50:50 ratio of males:females in the population. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate. The population at risk was estimated by dividing the alongshore extrapolation of P_M by the estimated larval entrainment.

Taxon	Estimated Annual Larval Entrainment	Estimated Annual Source Water Population at Risk	2·*FH*	*AEL*	P_M Alongshore Extrapolation	P_M Offshore Extrapolation
CIQ goby complex	33,927,750	15,749,000,000	85,418	*	0.21% (76.7 km)	**
spotfin croaker	20,896,741	58,199,000,000	*	*	0.04% (33.9 km)	0.04%
northern anchovy	16,293,995	6,807,000,000	52,472	365,837	0.24% (94.8 km)	0.12%
queenfish	5,339,449	7,435,000,000	14	*	0.08% (91.5 km)	0.05%
white croaker	5,284,106	5,519,000,000	36	*	0.10 % (75.4 km)	0.04%
salema	3,506,783	–	*	*	–	–
combtooth blennies	2,148,242	2,992,000,000	2,450	*	0.07% (18.3 km)	**
black croaker	2,137,034	8,928,000,000	*	*	0.02% (55.1 km)	0.02%
diamond turbot	1,631,863	1,948,000,000	*	*	0.08% (49.4 km)	0.06%
California halibut	1,505,361	6,289,000,000	4	*	0.03% (76.2 km)	<0.01%
rock crab megalops	2,324,020	693,000,000	*	*	0.33% (100.3 km)	0.22%
Total	94,995,344	114,559,000,000				

* No estimate due to either insufficient life history information or low abundance in entrainment samples.

** No extrapolation to offshore areas because the taxon has an exclusively alongshore distribution.

– *ETM* values could not be calculated because there were no surveys during which salema larvae were present in both entrainment and source water samples.

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

ADCP	acoustic Doppler current profiler
AEL	adult equivalent loss
CDFG	California Department of Fish and Game
cfs	cubic feet per second
CIQ	*Clevelandia, Ilypnus, Quietula*
cm	centimeters
cm/s	centimeters per second
CWA	Clean Water Act
CWIS	cooling water intake system
EAM	equivalent adult model
ETM	Empirical Transport Model
FH	fecundity hindcasting
ft	feet
ft/s	feet per second
g	grams
gal	gallons
gpm	gallons per minute
HBGS	Huntington Beach Generating Station
I&E	Impingement and Entrainment
in	inches
kg	kilograms
km	kilometers
lb	pounds
m	meters
m^3	cubic meters
mgd	million gallons per day
MLLW	mean lower low water
mm	millimeters
m/s	meter per second
MW	megawatts
NL	notochord length
NPDES	National Pollutant Discharge Elimination System
OTC	once through cooling
PacFIN	Pacific Fisheries Information Network
PE	proportional entrainment
PFMC	Pacific Fisheries Management Council
PLD	planktonic larval duration
P_m	probability of mortality
RecFIN	Recreational Fisheries Information Network
RWQCB	California Regional Water Quality Control Board
SCB	Southern California Bight
SL	standard length
TLF	total lifetime fecundity
YOY	young-of-the-year

1.0 Introduction

1.1 Background and Overview

Poseidon Resources Corporation proposes to build and operate the 50 mgd Huntington Beach Desalination Facility (HBDF). The facility will be located adjacent to the AES Huntington Beach Generating Station (HBGS) on a site currently occupied by unused fuel oil storage tanks. The proposed facility will convert a fraction of HBGS's condenser cooling seawater discharge into fresh drinking water using a reverse osmosis desalination process. Source water for this facility will be taken from the existing HBGS condenser cooling-seawater discharge system, which is permitted to circulate up to 507 mgd of seawater for cooling purposes. After the seawater passes through the HBGS's condensers, the desalination facility will intake approximately 100 mgd of HBGS's cooling water and produce 50 mgd of high-quality potable drinking water for use by residents and businesses in Orange County. The remaining 50 mgd becomes concentrated seawater, which will be discharged into the cooling water discharge system downstream of the desalination facility's intake point where it will mix with up to 407 mgd of HBGS's condenser cooling circulation system flow for dilution prior to discharge back into the Pacific Ocean.

As discussed, the desalination facility will withdraw its feedwater from the existing HBGS condenser cooling water discharge system through a direct connection into the discharge lines. Since the desalination facility will reuse the generating station's cooling water discharge after its permitted use, the desalination facility will not require a new seawater intake or any additional seawater directly from the ocean. In addition, the HBGS cooling water intake system (CWIS) also protects the desalination facility's intake against impingement losses.

However, if in the future, the HBGS were to cease the use of once-through cooling, or if the HBGS were to permanently alter their cooling water system's historical operations and reduce its seawater intake to less than 152 mgd, the proposed seawater desalination facility would intake water directly from the Pacific Ocean via the existing HBGS intake pipe in order to bring in 152 mgd. The desalination facility would use 52 mgd of the 152 mgd for diluting the discharged concentrated seawater.

1.1.1 Regulatory Setting

Growing public awareness and concern for controlling water pollution led to enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the Clean Water Act (CWA). The CWA established the basic structure for regulating discharges of pollutants into the waters of the U.S. It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry. The CWA also continued requirements to set water quality standards for all contaminants in surface waters. The CWA made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.

When water is withdrawn from a source water body for industrial purposes, organisms within the water body may be entrained or impinged. Water intake systems can affect source water populations by uncompensated removal of larvae that are entrained in cooling water flows and removal of larger life stages that are impinged on the intake screens. The CWA addresses the effects of cooling water intake systems on water bodies under Section 316(b).

Section 316(b) is a technology-based regulation that requires intake systems to apply Best Technology Available (BTA) to reduce and minimize the effects of the intake and to mitigate potential entrainment and impingement impacts. Although the intent of Section 316(b) regulation is described briefly in the CWA, the implementation of Section 316(b) has been greatly expanded upon in EPA development documents and by various administrative and judicial rulings over the years. In addition, under the Section 316(b) rule, large industrial facilities and power generating facilities require a National Pollution Discharge Elimination System (NPDES) permit approved in California by the State Water Resources Control Board.

The intake designs of most of the coastal- and bay-sited generating stations in California include vertical traveling screens fitted with 3/8-inch stainless steel mesh screens to prevent the entrainment of organisms larger than this size through the plant's seawater cooling system. The 3/8 inch size mesh screens out organisms large enough to survive removal and return to the source waterbody and at the same time allows smaller organisms that will not affect operation of the plant condenser system to pass through the generating station.

The HBGS is subject to regulations of the Clean Water Act, including the requirements of Section 316(b). Compliance with this and other sections of the state and federal water codes is regulated under an NPDES permit approved by the Santa Ana Regional Water Quality Board.

Recent studies on the effects of the HBGS cooling water intake system (CWIS) have been conducted in connection with a re-powering project certified by the California Energy Commission (CEC), which required AES to perform a study of the power plant's CWIS as a condition of re-powering certification. The CEC study was not a 316(b) study, but was designed using the same sampling methodologies and data analyses employed in several recently completed 316(b) studies (Tenera 2000a, 2000b, 2001). The results of the CWIS Impingement Mortality and Entrainment (IM&E) Characterization Study were also submitted to the Santa Ana Regional Water Quality Control Board to comply with provisions of the HBGS NPDES permit that required compliance with provisions of the 316(b) Phase II regulations.

A second, but unrelated study at the site was conducted to provide information for the HBDF EIR submittal to the City of Huntington Beach and other interested parties. This study was designed to investigate the potential for desalination facility feedwater intake withdrawn from

HBGS discharge flows to increase HBGS entrainment mortality and assess the significance of this potential entrainment effect on the source water.

In June, 2009, the State Water Resources Control Board released a draft policy requiring reductions in impingement and entrainment effects. If adopted, this policy may require the power plants to alter or cease operations of the once through cooling system. It should be noted that this draft policy does not apply to desalination projects. The Huntington Beach Desalination Facility will be permitted under the Porter Cologne Act.

1.2 Proposed Huntington Beach Desalination Facility

As currently permitted, the HBDF's feedwater will come directly from the cooling water discharge flow of the HBGS. The proposed desalination facility's withdrawal of feedwater from the HBGS cooling water discharge is not subject to 316(b) rules since the cooling water has already served its regulated purpose and:

- HBDF does not directly withdraw seawater from the ocean (HBGS withdraws the seawater with its intake pumps);
- HBDF withdraws the water on the discharge side once the cooling water has served its regulated purpose;
- HBDF water needs do not change the HBGS seawater pumping requirements; and
- HBDF does not require the HBGS to increase the quantity of water withdrawn or the velocity of the water withdrawn.

The study, analysis and impact assessment in this report examines the potential impingement and entrainment effects on the marine environment of using the existing HBGS intake as the feedwater for the HBDF absent the above conditions. In the event the HBDF begins operating in a standalone condition and not in coordination with the HBGS cooling water system, the following will be required for HBDF operations:

- HBDF will directly withdraw seawater from the ocean through the existing HBGS intake structure;
- HBDF will operate in a "stand alone condition" withdrawing 152 mgd of seawater. Approximately 100 mgd will be used to produce 50 mgd of high-quality potable drinking water for use by residents and businesses in Orange County. The remaining 50 mgd of higher concentrated seawater will be diverted back into the existing HBGS' discharge system downstream of the desalination facility's intake point where it will mix with the remaining 52 mgd of seawater for dilution prior to discharge back into the Pacific Ocean; and
- The reduced HBDF intake flow velocity will be less than the existing HBGS permitted conditions.

1.3 Study Plan Objectives

This Intake Effect Assessment study plan is designed to address the following specific questions for HBDF in a standalone operating condition:

- What are the composition and abundance of species that could be impinged (organisms trapped on the intake screening systems) due to the operation of the effect of the HBDF feedwater intake of 152 mgd?
- What are the composition and abundance of species that could be entrained by the HBDF feedwater intake of 152 mgd?
- How might any losses due to feedwater impingement and entrainment affect the source populations of the affected species in the Southern California Bight?
- Are these losses ecologically or economically significant?

Since the purpose of this report is to examine the effects of operation of the HBDF under standalone condition, the data and results from the in-plant feedwater intake study are not included. This report presents data collected from the HBGS CWIS IM&E Characterization Study, which has been reanalyzed using the proposed HBDF feedwater intake volume of 152 mgd.

1.4 Report Organization

This report describes the HBDF intake system and assesses the potential effects entrainment and impingement through an assessment of data collected as part of the HBGS CWIS 316(b) studies. Section 2.0 provides a description of the project and Section 3.0 describes the environmental setting. Section 4.0 presents the results of the source water and entrainment studies. Impingement impacts are discussed in Section 5.0. An assessment of the entrainment and impingement impacts on source populations is provided in Section 6.0 and the literature cited in the report is listed in Section 7.0. Appendix A provides the impact assessment modeling formulation, Appendix B presents the HBGS entrainment and source water data by survey, and Appendix C provides the HBGS impingement data by survey. Appendix D presents a study of the cumulative impacts of HBDF and southern California coastal power plant water intakes on the mortality of larval fish and invertebrates.

2.0 Description of the Huntington Beach Generating Station and Proposed Desalination Facility

The following section describes the HBGS and the surrounding aquatic environment. A description of the generating station and its cooling water intake system (CWIS) is presented in Sections 2.1 and 2.2. A description of the physical and biological environments in the vicinity of the HBGS is presented in Section 2.3.

2.1 Description of the Generating Station

The HBGS is located on the Orange County coast in the city of Huntington Beach, California, midway between Point Fermin and Dana Point (**Figure 2-1**). The generating station consists of four steam-powered electric generating units. Steam is supplied to each turbine generator from oil- and gas-fired boilers. Units 1 and 2 are each rated at 215 megawatts (MW) and Units 3 and 4 are each rated at 225 MW. Units 3 and 4 were operated very sparingly after 1989 and were retired from service from 1995 until completion of the retool project in 2003. Unit 5, a multiple-jet-turbine peaker unit (133 MW), was retired from service in 2002. The current total station rating is 880 MW.

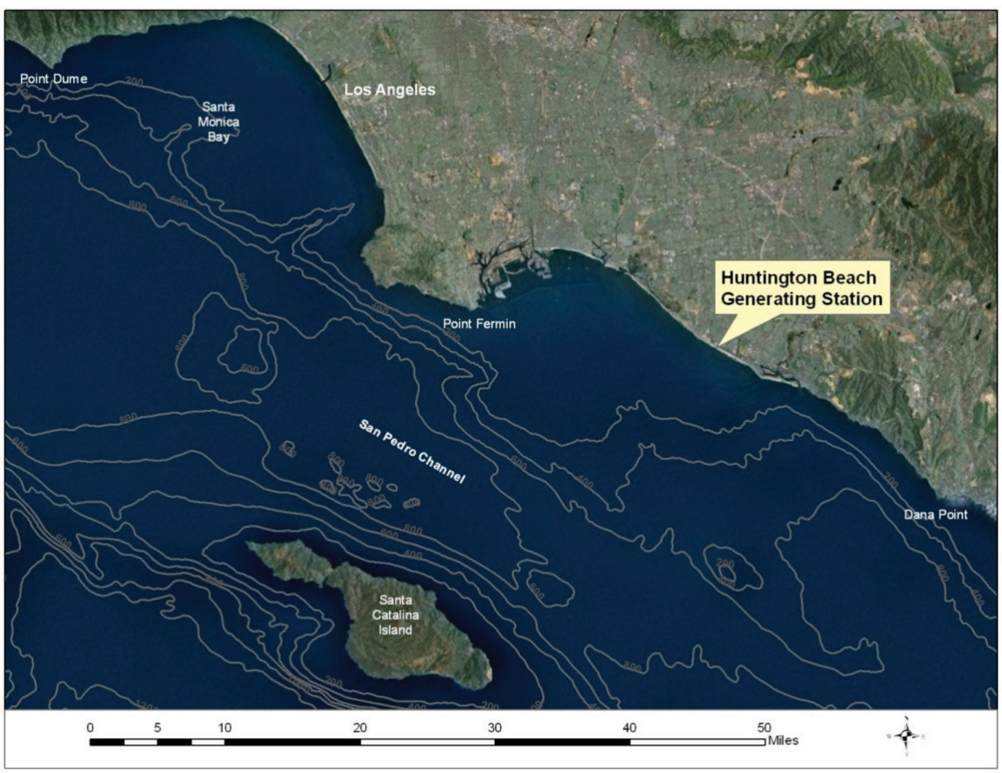

Figure 2-1. Location of the Huntington Beach Generating Station in southern California.

2.2 Description of the Cooling Water Intake System

Ocean water for cooling purposes is supplied to the generating station via a single cooling water system. Seawater for Units 1–4 is withdrawn from an intake structure located 457 m (1,500 ft) offshore. The intake structure is located in approximately 10 m (33 ft) of water, and rises approximately 4 m (13 ft) off the bottom. The vertical riser section is 6.4 m inside-diameter (ID), and the horizontal conduit to the generating station is 4.3 m (21 ft) ID. The vertical riser is fitted with a velocity cap, and the vertical opening between the riser and the velocity cap is about 1.5 m (5 ft). Entrance velocities between the riser and the velocity cap have been measured at 0.6 m/sec (2 fps) for full flows of 356,600 gpm (permitted 514 mgd) (McGroddy et al. 1981).

Seawater is drawn into the plant by up to eight circulating water pumps, each capable of delivering 44,000 gallons per minute (gpm), or about 63.4 mgd, for a station maximum of about 507 mgd (1,919,000 m^3). The flow is directed to a 4 m x 15.2 m (13 ft x 50 ft) open rectangular forebay and screening facility within the plant. The screen system is composed of vertical bar racks spaced 76.2 mm (3”) on center and vertical traveling screens with 9.5-mm (3/8”) mesh designed to remove trash, algae, marine life, and other incidental debris incoming with the cooling water. After flowing through the screen system, the cooling water is pumped to two steam condensers, one per turbine generator. At full load, the temperature increase through the condensers (ΔT) is approximately 10°C (18°F). After passing through the condensers the water is directed to a single 4.3-m (14 ft) ID concrete discharge conduit, which extends approximately 366 m (1,200 ft) offshore. The discharge structure resembles the intake structure, except there is no velocity cap. Discharged waters are directed vertically to the surface to allow for dilution and atmospheric cooling.

Units 1–4 have closed cooling water systems to cool auxiliary equipment. Demineralized water is cooled by part of the main cooling stream, which is diverted to a heat exchanger and returned to the main stream. Each unit diverts about 9,750 gpm (14 mgd), and this water is subsequently elevated 4.6°C (8.3°F) (AES and URS 2000). No modifications to the cooling water system were made as part of the Retool Project on Units 3&4 completed in 2003.

To control the growth of bacteria and other micro-fouling organisms within the cooling water system, the cooling water is treated with sodium hypochlorite in accordance with the station’s NPDES permit. Biofouling within the cooling water conduits and forebay is controlled by heat treatment. During heat treatments, a portion of the heated discharge water is diverted into the forebay and intake conduits until the water temperature rises to approximately 40.5°C (105°F). Temperature of discharge waters during this procedure is about 44° to 50°C (112° to 122°F). This temperature is maintained for about one hour, during which time all mussels, barnacles, fishes, and other invertebrates within the cooling water system succumb to the high water temperature. This procedure has been used for decades at most of southern California’s coastal generating stations (Graham et al. 1977), and is done in compliance with NPDES permit limitations. Divers also periodically remove accumulated debris, such as mussel and barnacle shells and sand, from the forebay and in-plant conduits.

2.3 Desalination Facility Design Characteristics

The Huntington Beach Desalination Facility will be a reverse osmosis seawater treatment facility, which will be located adjacent to the Huntington Beach Generating Station on a 13-acre site currently occupied by unused fuel oil storage tanks. The proposed facility will convert a fraction of HBGS's condenser cooling seawater discharge into fresh drinking water using a reverse osmosis desalination process. Source water for this facility will be taken from the existing HBGS condenser cooling-seawater discharge pipeline system, which is permitted to circulate up to 507 mgd of seawater for cooling purposes. After the seawater passes through the HBGS's condensers, the desalination facility will intake approximately 100 mgd of HBGS's cooling water and produce 50 mgd of high-quality potable drinking water for use by residents and businesses in Orange County. The remaining 50 mgd becomes concentrated seawater, which will re-enter the HBGS condenser cooling water discharge system downstream of the desalination facility's intake point and blend with up to 407 mgd of HBGS's condenser cooling circulation system flow for dilution prior to discharge back into the Pacific Ocean.

The proposed HBDF consists of the following key facilities:

- Intake connection to the power plant discharge lines
- Intake fine mesh screens (microscreens) equipped with marine organism retrieval and return system
- Intake pumps
- Pretreatment filtration system
- Reverse osmosis membrane system
- Product water disinfection and storage facilities
- Concentrate and filter backwash discharge system
- Discharge pipeline connection to power plant discharge outfall

The desalination plant intake will be connected to the two existing 108-inch power plant cooling water discharge lines via two separate 72-inch intake pipelines. The two desalination plant intake pipelines will connect directly on one side of the power plant discharge lines. The two intake lines will join into one 72-inch intake pipeline ahead of the desalination plant intake microscreens.

The velocity of the 108-inch power plant discharge line at the point of interconnection with the desalination plant's 72-inch intake pipeline will vary depending on the power plant discharge flow:

- At *minimum* power plant discharge flow of 152 mgd, the 108-inch discharge pipeline velocity will be 3.6 fps assuming all the discharge flow is conveyed through one of the two discharge lines only. If the flow is split between the two 108-inch discharge pipelines, the velocity will be 1.8 fps. Typically, at minimum flow, only one of the two 108-inch lines is used for discharge (i.e. the minimum discharge velocity is 3.6 fps).

- At a power plant discharge flow of 234 mgd, the 108-inch discharge pipeline velocity will be 5.7 fps assuming all the discharge flow is conveyed through one of the two discharge lines only. If the flow is split between the two 108-inch discharge pipelines, the velocity will be 2.9 fps.

- At *maximum* power plant discharge flow of 514 mgd, the 108-inch discharge pipeline velocity will be 12.5 fps assuming all the discharge flow is conveyed through one of the two discharge lines only. If the flow is split between the two 108-inch discharge pipelines, the velocity will be 6.3 fps. Typically, at maximum flow, both 108-inch lines are used for discharge (i.e. the maximum discharge velocity is 6.3 fps).

At the point where the power plant cooling water enters the 72-inch desalination plant intake pipeline, the cooling water will be under 4 to 5 psi (9 to 12 feet H_20) of pressure. This available pressure will be adequate to convey the water into desalination plant intake facilities and push the water through the intake microscreens without additional pumping. The entrance velocity of the seawater in the 72-inch seawater desalination plant intake pipeline will be the same at all modes of power plant operations. At design desalination plant intake flow of approximately 100 mgd, this pipe entrance velocity will be 5.8 fps.

All desalination plant intake seawater will be screened through four microscreens, which will be located upstream of the desalination plant intake pumps. These facilities will be equipped with microscreens with 120-micron openings. The size of the openings is dictated by the size of particles that must be removed from the seawater for the protection of the downstream desalination plant facilities (pre-treatment filters and reverse osmosis system).

The microscreens will have two key functions:

- To retain, recover and return to the ocean seawater particles/solids and marine organisms larger than 120 microns, which are left in the water after intake water screening through the existing HBGS intake's 3-inch bar racks and 3/8-inch fine screens.

- To protect downstream desalination plant equipment from biological and solids fouling.

3.0 Environmental Setting and Characteristics of the Source Water

The marine setting for the Huntington Beach Desalination Facility (HBDF) is part of a larger oceanographic unit known as the Southern California Bight. The Southern California Bight comprises the offshore area reaching from Point Conception to the north and below the California/Mexican border to the south and extending outward from the shore to a distance where the ocean depth is approximately 200 fathoms (and inshore of the Santa Rosa Ridge). Although geographically identified by these boundaries, it is a region that is more accurately defined by its patterns of ocean currents, temperatures, and climatic setting. It is a dynamic oceanographic region where the area's populations of fishes and other marine organisms fluctuate in response to environmental alterations such as El Niño events. The Southern California Bight is also bordered by the most densely human populated coastal region in California and is consequently affected to varying degrees by associated pollution and shoreline development.

3.1 Physical Description

The physical and biological characteristics of the subtidal environment off Huntington Beach have been studied extensively by the HBGS operators (SCE and AES Huntington Beach L.L.C.) and by the Orange County Sanitation District (OCSD), which discharges primary- and secondary-treated wastewater from a diffuser outfall about four nautical miles offshore the generating station in about 60 m (197 ft) of water. Studies performed for the generating station have examined the physical and biological characteristics of the nearshore zone (depths to about 10 m [33 ft]), while studies performed by OCSD have been focused in deeper waters around the wastewater outfall.

The coastline of Huntington Beach runs, in general, from west-northwest to east-southeast. The continental shelf offshore of the generating station is gently sloping; the 30 m (98 ft) isobath is nearly 6.4 km (4 mi) from shore. Subtidal sediments are predominantly sand, with lesser amounts of silt and clay (OCSD 2000, 2003a). Off Huntington Beach, grain size generally decreases with depth, grain size generally increases upcoast from the OCSD wastewater outfall, and the Newport and San Gabriel submarine canyons (downcoast and upcoast of the generating station, respectively) are depositional areas. The nearest stand of giant kelp (*Macrocystis pyrifera*) is located inside the Newport Harbor entrance jetty 11.0 km (6.8 mi) downcoast.

In general, alongshore currents show a seasonal pattern in net flow: equatorward from early December to early May (5–10 cm/s), and poleward the rest of the year (Sverdrup and Fleming 1941, Crowe and Schwartzlose 1972, Hickey 1979). However, this is not always the case, such as during the summer 2001 when there was a substantial down-coast mean current over the San

Pedro shelf with a maximum near the surface on the outer shelf. At depths below about 70 m (230 ft), an undercurrent flow was predominantly up-coast, that occasionally rose to depths of 30 m (98 ft) for periods of a few days (Noble et al. 2003). This feature has been previously observed, with an 11 m (36 ft) deep current meter situated between these two flows (Hendricks 1993). The surface mean current is generally unrelated to local winds over the shelf (Noble et al. 2003). However, there is some indication that large-scale fluctuations in shelf currents may be generated by coastal-trapped waves propagating from Baja California (Hickey 1992, Noble et al. 2003).

While the influence of the local wind field on regional currents is small, it does play a role with nearshore currents. As a result, flows in the nearshore may be in the opposite direction to flows over the middle and outer shelf (Noble et al. 2003). In this region, winds show a strong diurnal pattern, generated by differential heating of the land that produce strong onshore winds in the afternoon. Afternoon winds force surface waters directly and drive an onshore flow that piles up water at the shoreline (Noble et al. 2003). As a result, downwelling should occur near the shoreline. As the winds die down in the evening, nearshore waters relax, resulting in an offshore flow that causes upwelling to occur. This vertical flow generates shoreline water temperature fluctuations of up to three degrees (Noble et al. 2003). Based on these observed temperatures, most of this vertical exchange occurs between the mixed layer and waters just below the mixed layer.

In summary, the coastal currents are complex and may vary seasonally. Mean currents parallel to the coast may be a few centimeters to decimeters per second. Cross-shelf currents are not well-characterized, but might have a mean velocity an order of magnitude lower. However, under certain conditions, internal waves may rapidly transport water several km across the shelf for short time periods.

3.1.1 Huntington State Beach

The HBGS is located just across Pacific Coast Highway (inland) from the Huntington State Beach, and the intake and discharge structures for the generating station are just offshore the state beach. The state beach is a little over two miles in length, extending north from the Santa Ana River mouth past the generating station to Beach Boulevard. At Beach Boulevard, the state beach borders the Huntington City Beach. Over 11 million people visit the beaches of Huntington Beach annually.

3.1.2 Santa Ana River and Talbert Marsh

The mouth of the Santa Ana River is approximately 2.4 km (1.5 mi) downcoast from the generating station. The Santa Ana River is the largest river system in southern California, with a watershed of about 634,550 ha (2,450 mi^2). Flow volume in the river is intermittent, and is partially dependent on the amount of precipitation in the watershed. Diversion and storage of water behind dams during winter and subsequent slow release during summer result in continual flow in some stretches of the river that would be dry otherwise (MBC 2000). In addition, there is year-round input from dischargers, including wastewater treatment facilities. Talbert Marsh is a recently restored salt marsh located just west of the Santa Ana River mouth. The marsh, which was previously isolated from tidal exchange, was restored in the late 1980s, and is connected to the ocean through a 30 m (98 ft) wide entrance channel adjacent to the river mouth. Both the Santa Ana River and Talbert Marsh are sources of fecal indicator bacteria (fecal coliform and *Enterococcus*) during ebb tides, and these bacteria are transported parallel to shoreline resulting in frequent beach postings in the vicinity of the generating station (Kim et al. 2004).

3.2 Biological Resources

The following section describes the aquatic biological communities in the vicinity of the HBDF, including both invertebrate and fish communities.

3.2.1 Invertebrate Communities

Infaunal organisms off Huntington Beach were studied annually from 1975 through 1993 (MBC 1993). In the 19 years of sampling, an average of 43 individuals representing 17 species were collected per liter of sediment. Dominant species included the polychaetes *Apoprionospio pygmaea* and *Goniada littorea*, the amphipod *Rhepoxynius menziesi*, the cumacean *Diastylopsis tenuis*, and the gastropod *Olivella baetica*. These species are common in the sandy nearshore environments of southern California (Morris et al. 1980).

Diver surveys at four to six locations offshore the generating station were conducted annually from 1975 through 2001 (MBC 2001). On average, divers observed 34 benthic macrofaunal species per year during the surveys, though interannual variation was high, ranging from 22 species in 1975 to 55 species in 1984. Average density of organisms recorded by divers was 61 individuals per m^2, with values ranging from 12 individuals per m^2 (1976 and 1977) to 161 individuals per m^2 (1989). In 2001, biologist-divers recorded 25 species at an average density of 51 individuals per m^2. Polychaete worms were numerically dominant in 2001, comprising 79% of the total abundance, followed by arthropods with 13%. A single species, the onuphid polychaete *Diopatra splendidissim*a, accounted for 75% of the abundance. This species provides stability to the sediments and enhances the diversity of the bottom community by providing habitat for macrofaunal inhabitants of the shallow sandy subtidal. The density of many other macrofaunal species is intimately tied to that of *Diopatra. Diopatra* tubes are colonized by larval organisms that require stable substrate for attachment, such as slipper snails, kelp scallops, barnacles, hydroids, bryozoans, and tube-building amphipods. Small, unidentified spider crabs (Majidae) comprised 9% of the abundance in 2001, followed by the slippersnail *Crepidula adunca* (4%), maldanid worms (3%), barnacles in the genus *Balanus* (3%), and brittlestars (Ophiuroidea; 2%).

A total of 10 epibenthic macroinvertebrate species was collected during the 2001 trawl surveys offshore the generating station (MBC 2001). The most abundant species was the spiny sand star (*Astropecten armatus)*, comprising 34% of trawl-caught abundance. Other abundant trawl-caught invertebrates included the penicillate jellyfish (*Polyorchis penicillatus*; 24%), tuberculate pear crab (*Pyromaia tuberculata*; 18%), blackspotted bay shrimp (*Crangon nigromaculata*; 14%), and Pacific sand dollar (*Dendraster excentricus*; 5%).

A total of 30 macroinvertebrate species was collected in the 2002 fish impingement surveys at the generating station (MBC 2003a). The dominant species were the opalescent nudibranch (*Hermissenda crassicornis*), yellow crab (*Metacarcinus anthonyi*), frond-aeolis (*Dendronotus frondosus*), tuberculate pear crab, and Pacific rock crab (*Romaleon antennarius*). From 1994 through 2002, other abundant species impinged at the generating station were giant frond-aeolis (*Dendronotus iris*), penicillate jellyfish, red rock shrimp (*Lysmata californica*), common salp (*Thetys vagina*), California aglaja (*Navanax inermis*), and graceful crab (*Metacarcinus gracilis*).

The intertidal community adjacent to the generating station was studied quarterly in 1971 and 1972 (EQA/MBC 1973). The major components of the intertidal community were the polychaetes *Hemipodus borealis*, *Nephtys californiensis*, and *Nerinides acuta*, Pacific sand crab (*Emerita analoga*), Pismo clam (*Tivela stultorum*), and bean clam (*Donax gouldii*). Species richness and densities of these species were lower than those recorded at similar sites in southern California. It was concluded that several factors, potentially including wave action and disturbance from beach-goers, limited the population.

3.2.2 Fish Communities

Demersal fish surveys were conducted off the HBGS annually since 1976 (MBC 2001). Six to twelve trawls were performed at stations directly offshore the generating station, and 1.6 km (1 mile) upcoast and downcoast from the generating station. At least 64 species of fishes have been collected in the trawl surveys. The catch was numerically dominated by northern anchovy (*Engraulis mordax*; 50%), white croaker (*Genyonemus lineatus*; 27%), and queenfish (*Seriphus politus*; 18%). Combined, these three species accounted for more than 95% of the trawl-caught fish abundance.

Other historically abundant species include surfperches, such as white seaperch (*Phanerodon furcatus*), walleye surfperch (*Hyperprosopon argenteum*), barred surfperch (*Amphistichus argenteus*), and shiner perch (*Cymatogaster aggregata*), and flatfishes such as California halibut (*Paralichthys californicus*) and speckled sanddab (*Citharichthys stigmaeus*). Numbers of several surfperches collected by trawl and in fish impingement surveys declined by more than 90% between 1979 and 1984, and abundances have remained relatively low since then. This coincided with a warming of ocean waters in southern California (Beck and Herbinson 2003), as well as a decrease in upwelling (Allen et al. 2003). Numbers of California halibut collected by trawl declined in 1994 when sampling effort was halved.

In-plant fish impingement sampling at HBGS has been conducted since the 1970s. From 1979 through 2002, queenfish was the dominant species in impingement samples, comprising 82% of the total abundance (MBC 2003a). Similar to trawl catches off the generating station, white croaker and northern anchovy were also abundant in impingement samples, accounting for 6% and 3% of the total abundance, respectively. Other abundant species were walleye surfperch, white seaperch, Pacific pompano (*Peprilus simillimus*), California grunion (*Leuresthes tenuis*), jacksmelt (*Atherinopsis californiensis*), shiner perch, and deepbody anchovy (*Anchoa compressa*). Similar to long-term trends observed in the trawl data, numbers of walleye surfperch, white seaperch, and Pacific pompano declined dramatically from 1979 through 1984. In 2002, the most abundant fish species impinged were queenfish (83%), white croaker (4%), shiner perch (2%), jacksmelt (2%), and deepbody anchovy (1%).

Commercial fishery species prevalent off of Huntington Beach include Pacific sardine (*Sardinops sagax*), market squid (*Loligo opalescens*), Pacific mackerel (*Scomber japonicus*), northern anchovy, California spiny lobster (*Panulirus interruptus*), and jack mackerel (*Trachurus symmetricus*). The pelagic species (Pacific sardine, market squid, Pacific mackerel, northern anchovy, and jack mackerel) are generally caught by purse seine, drum seine, and long-line, while California spiny lobster are collected by crab/lobster trap.

In 1987, seven species of fishes were collected by a variety of methods from the tidally influenced lower Santa Ana River, which is concrete-lined (Marsh 1992). Only two species were native: California killifish (*Fundulus parvipinnis*) and striped mullet (*Mugil cephalus*). The other five species were introduced, and included common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), mosquitofish (*Gambusia affinis*), green sunfish (*Lepomis cyamellus*), and Mozambique tilapia (*Oreochromis mossambicus*). Of these seven species, only three were impinged at the HBGS from 1979 through 2002.

From 1989 through 1990 eleven species of fishes were collected by beach seine from Talbert Marsh (Gorman et al. 1990). California killifish, topsmelt (*Atherinops affinis*), Pacific staghorn sculpin (*Leptocottus armatus*), and arrow goby (*Clevelandia ios*) were the most abundant species. Fishes collected in small numbers (10 individuals or less) included shiner perch, white croaker, longjaw mudsucker (*Gillichthys mirabilis*), walleye surfperch, bay goby (*Lepidogobius lepidus*), California halibut, and bay pipefish (*Syngnathus leptorhynchus*).

4.0 Cooling Water Intake Structure Entrainment and Source Water Study

4.1 Introduction

The purpose of the entrainment study done in 2003–2004 (MBC and Tenera 2005) was to determine the extent of potential impacts from the operation of the cooling water system of the HBGS on larval fishes and selected invertebrate larvae (target species). Entrainment refers to the withdrawal of aquatic organisms from the source water into and through the cooling water intake system of the generating station. The entrainment study focused on larval life stages, while the impingement study focused on juvenile and adult forms.

To determine the potential effects of the proposed Poseidon Resource desalination facility on larval fishes and selected invertebrates, the data from the 2003–2004 study were reanalyzed using the proposed volume of the Poseidon Resource desalination facility if it was operated independently from the HBGS. The daily intake flow of 1.92×10^6 m^3 (507×10^6 gal [507 mgd]) used in all of the impact assessment calculations from the original study for the HBGS cooling water system was reduced to the proposed flow of 5.75×10^5 m^3 (152×10^6 gal [152 mgd]) for the desalination facility.

As part of studies done for previous permitting for the desalination facility, plankton samples were collected from the discharge side of the cooling water supply at a location that approximated the location of the proposed desalination feedwater supply. These data were intended to be representative of larval concentrations and condition after the cooling water had passed through the intake tunnels and condensers. Rather than using larval concentrations at the point of intake for the desalination facility the focus is now on effects on the source water when the plant is operated in standalone configuration. Therefore, the data collected from inside the cooling system will not be included in this reanalysis.

4.1.1 Species to be Analyzed

A diverse array of planktonic organisms are susceptible to entrainment. The intent of this study was to estimate entrainment effects on two types of organisms: fish larvae and late-stage invertebrate larvae of the following species: cancrid crabs, market squid (*Doryteuthis opalescens*), California spiny lobster (*Panulirus interruptus*), ridgeback rock shrimp (*Sicyonia ingentis*), and Pacific sand crab (*Emerita analoga*). Assessment of entrainment effects was limited to the target invertebrate larvae and to the most abundant fish taxa that together comprised 90% of all larvae entrained. The same selection criteria applied to juvenile and adult fishes impinged by the generating station.

4.2 Methods

4.2.1 Field sampling

The sampling methodologies to determine composition and abundance of ichthyoplankton entrained by the generating station were described in detail in MBC and Tenera (2005). To summarize, sampling in the immediate proximity of the cooling water intake was conducted twice monthly in September and October 2003, weekly from November 2003 through July 2004, and twice during August 2004. During each sampling event, two replicate tows at the entrainment station were collected four times per 24-hr period—once every six hours. Sampling was conducted offshore (within 100 m [328 ft]) of the submerged intake structure (**Figure 4-1**) using an oblique tow that sampled the water column from approximately 13 cm (5.12 in) off the bottom and then back to the surface. Two replicate tows were taken with a minimum target sample volume of 30 to 40 m^3 (7,925 to 10,567 gal) for each net on the bongo frame.

The wheeled bongo frame was fitted with 60 cm (23.6 in) diameter net rings with plankton nets constructed of 333-µm Nitex® nylon mesh. Each net was fitted with a Dacron sleeve and a cod-end container to retain the organisms. Each net was equipped with a calibrated General Oceanics® flowmeter, allowing the calculation of the amount of water filtered. At the end of each tow, nets were retrieved and the contents of the net rinsed with seawater into the cod-end. Samples were then transferred to prelabeled jars containing preservative.

Source water sampling was conducted monthly in September and October 2003, twice per month from November 2003 through July 2004 (during the peak spawning period for fishes in late winter and spring), and once in August 2004. Only the samples initially preserved in formalin from the first of the two bimonthly source water surveys (November through July) were processed, with the samples from the second monthly survey archived for potential future sorting and analysis. Besides the entrainment station, source water sampling occurred at six additional source water stations located upcoast, downcoast, and offshore from the intake structure (**Figure 4-1**). Tows were performed in the same manner as the entrainment tows (obliquely).

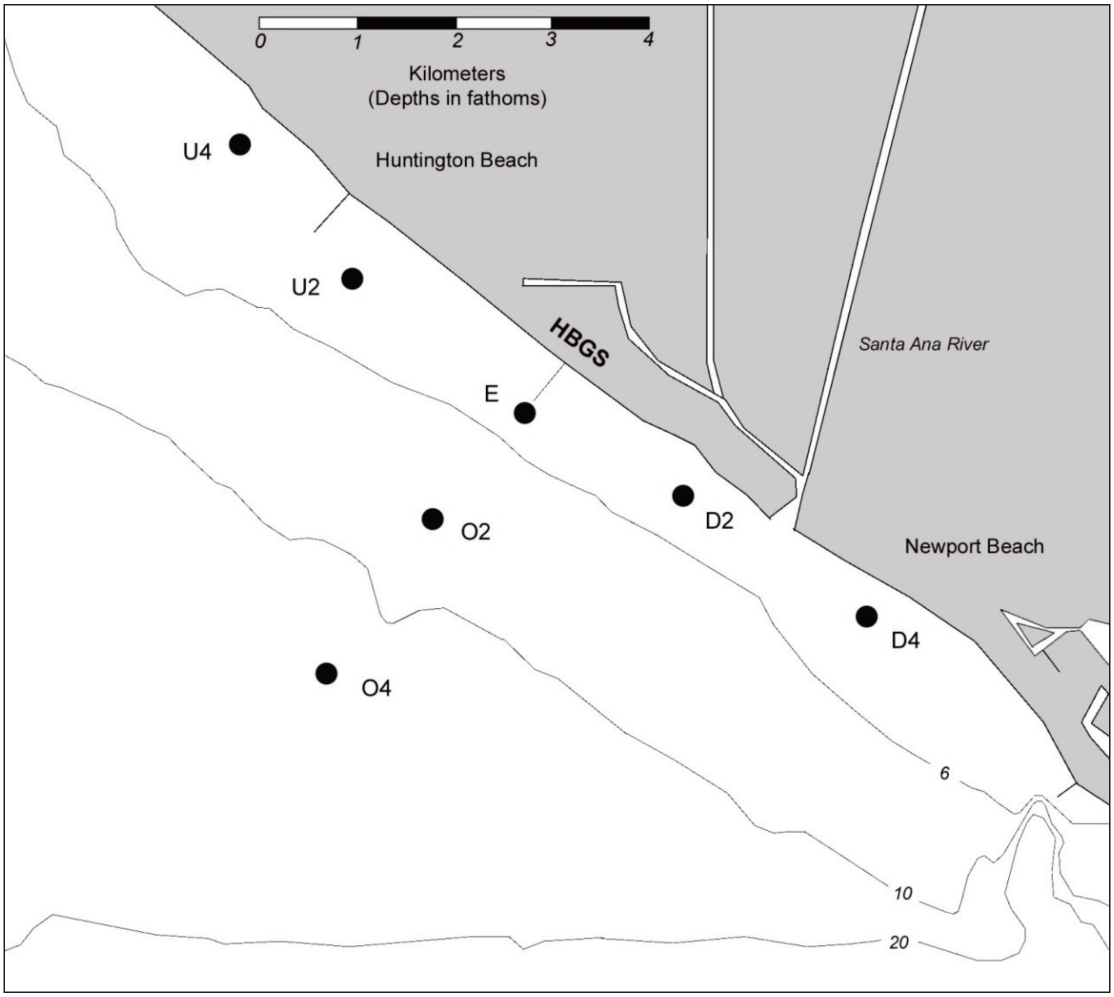

Figure 4-1. Location of entrainment (E) and source water sampling stations (U4, U2, D2, D4, O2, and O4), where U, D, and O designate stations upcoast, downcoast, and offshore of the intake, respectively.

4.2.2 Laboratory Analysis

Larval identification procedures were described in detail in MBC and Tenera (2005). To summarize, samples were examined under dissecting microscopes and fish larvae and targeted invertebrate larvae were separated from debris and other zooplankton. Larvae were identified to the lowest practical taxonomic level and enumerated. Fish eggs were not sorted or identified.

Some larval fishes could not be identified to the species level using microscopic techniques and were recorded at the lowest taxonomic classification possible (e.g., genus or family level). For example, many species of the family Gobiidae share morphologic and meristic characters during early life stages (Moser 1996) making identifications to the species level difficult. Larvae of the arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) are difficult to identify to species when they are newly hatched. Therefore, these three species were combined into an “unidentified goby” category referred to as the “CIQ goby complex”.

Larval combtooth blennies (*Hypsoblennius* spp.) can be easily distinguished from other larval fishes (Moser et al. 1996). However, the three sympatric species that could occur in the area cannot be distinguished from each other on the basis of morphometrics or meristics at the smaller sizes common in the samples. Therefore, the combtooth blennies were grouped into an “unidentified combtooth blennies” category (e.g., *Hypsoblennius* spp.).

A number of larvae from the Family Sciaenidae (croakers) were collected during the study. A great majority of yolk-sac stage larvae collected during the summer surveys belonged to the family Sciaenidae. Identification to the species level for these early developmental stages is very difficult because some of the species have similar initial pigmentation patterns along the dorsal margin, migrating down as the larvae develop. Despite the uncertainties in identifying the yolk-sac stages of Sciaenidae larvae, unidentified yolk-sac accounted for only 12% of the total sciaenid larvae collected from the entrainment station. Therefore, the individual species were not combined into a single group for analysis because of the difficulty in interpreting the results for a taxonomic grouping that includes both commercial and non-commercial species with varying life histories. In addition, the primary method of assessment, the Empirical Transport Model, uses an estimate of plant-induced mortality that would not be affected by small changes in the estimates from the entrainment and source water sampling as long as the proportion between the two estimates did not change.

The lengths (notochord/standard lengths) of larvae collected from the entrainment station were measured to estimate the age of the entrained larvae. A representative number of individual larvae of each of the most abundant taxa, or species with recreational or commercial fishery importance, collected during each survey, were measured using a video capture system and Optimus^{TM} image analysis software.

All of the modeling approaches used in this report for assessing impacts on larval forms require an estimate of the age of the larvae being entrained. The two demographic approaches used in assessing impacts, adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*) extrapolate estimates from the average age at entrainment, while the other approach, empirical transport modeling (*ETM*), estimates population-level mortality due to entrainment based on the period of time that the larvae are exposed to entrainment. These estimates were obtained by measuring a representative number of larvae from each of the target taxa from the entrainment samples and using published larval growth rates. Although a large number of larvae may have been collected and measured from entrainment samples, a random sample of 200 from the total measurements was used to calculate the average age at entrainment and total larval duration (all of the length data were used for taxa with less than 200 larvae). The average age at entrainment was calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by a larval growth rate obtained from the literature, while the period of time that the larvae were exposed to entrainment was calculated by dividing the difference between the size at hatching and the size at the 95th percentile by a larval growth rate obtained from the literature.

The duration of the egg stage was added to this value for species with planktonic eggs. The 95th percentile value was used to eliminate outliers from the calculations. The size at hatching was estimated as follows:

$$\text{Hatch Length} = (\text{Median Length} + 1^{st} \text{ Percentile Length})/2.$$

This calculated value was used because of the large variation in size among larvae smaller than the average length. This calculation assumes that the length frequency distribution is skewed towards smaller sized larvae and usually resulted in a value close to the hatch size reported in the literature. The length frequency distributions for several of the fishes did not follow this pattern and the length of the 10^{th} percentile of the distribution was used as the hatch length for these taxa to eliminate outlier values.

4.2.3 Data Analysis

The following sections describe how the collected data were processed and analyzed.

4.2.3.1 Entrainment Estimates

Entrainment estimates were calculated using larval concentrations from field samples and the proposed flow of 5.75×10^5 m^3 per day (152×10^6 gal per day [152 mgd]) for the desalination facility. The precursor to the *AEL* and *FH* calculations is an estimate of total annual larval entrainment (E_T). Estimates of larval entrainment at HBGS were based on weekly sampling where E_T is the estimate of total entrainment for the study period and E_i is the weekly entrainment estimate. Estimates of entrainment for the study period were based on two-stage sampling designs, with days within periods and cycles (four six-hour collection periods per day) within days. The within-day sampling is based on a stratified random sampling design with four temporal cycles and two replicates per cycle. The variance calculated for the day was extrapolated across the days within each sampling period.

4.2.3.2 Entrainment Impact Assessment

Assessment of entrainment effects were limited to the most abundant fish taxa (target taxa) that together comprised approximately 90% of the total estimated larvae entrained during the September 2003–August 2004 study period. Estimates of entrainment loss, in conjunction with demographic data collected from the fisheries literature, were used in modeling entrainment effects on target taxa using *FH* and *AEL*, when possible. Data for the same target taxa from sampling of the entrained larvae and potential source populations of larvae were used to calculate estimates of proportional entrainment (*PE*) and used to estimate the probability of mortality (P_m) due to entrainment using the *ETM*. In the HBGS entrainment and impingement studies each approach (e.g., *AEL*, *FH*, and *ETM*), as appropriate for each target taxon, was used to assess effects of power plant losses. Detailed mathematical formulation of the models is presented in **Appendix A**.

4.2.3.2.1 Demographic Models

Adult equivalent loss models evolved from impact assessments that compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert all these losses to adult equivalents. Horst (1975) provided an early example of the equivalent adult model (*EAM*) to convert numbers of entrained early life stages of fishes to their hypothetical adult equivalency. Goodyear (1978) extended the method to include the extrapolation of impinged juvenile losses to equivalent adults.

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We used two different but related demographic approaches in assessing entrainment effects at the HBGS: *AEL*, which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females whose reproductive output has been removed by entrainment of larvae. Both approaches require an estimate of the age at entrainment. These estimates were obtained by measuring a representative number of larvae of each of the target taxa from the entrainment samples and using published larval growth rates to estimate the age at entrainment. The age at entrainment was calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by the growth rate obtained from the literature.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of fecundity. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary, and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provides estimates of adult fish losses, which ideally need to be compared to standing stock estimates of adult fishes.

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa considered in this assessment. These rates when available are inferred from the literature along with estimates of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported. The accuracy of the estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates. The lack of demographic information for many species limits the use of these modeling approaches.

There were usually no estimates of variation available for the life history information used in the models. The ratio of the mean to standard deviation (coefficient of variation) was assumed to be 50% for all life history parameters used in the models.

4.2.3.2.2 ETM Model

The *ETM* analysis was applied for selections of two general species groups: open coast pelagic and nearshore. Pelagic species included anchovies, queenfish, croakers, flatfish and cancrid crabs. Nearshore species were gobies and blennies. Coastal current data were used to estimate alongshore and onshore components for estimating the potential source water area for open coast pelagic species. The alongshore component was used to estimate the coastal length of the source population of nearshore species.

The current data for both estimates used in the original analysis of the 2003–2004 study (MBC and Tenera 2005) were from data collected for the Orange County Sanitation District (OCSD) from June 1999 to June 2000 at Station Q offshore from the HBGS (**Figure 4-2**). The historical data used were collected at a single depth 5 m (16.4 ft) below the surface over a bottom depth of 14.8 m (48.5 ft) MLLW. There were two current meters at Station Q (at 5 and 10 m [16.4 and 32.8 ft] depths) which is located 1.47 km (0.9 mi) from the HBGS intake. The magnetic vectors for the analysis were corrected to true north using a 13.35º east variation. These true vectors were then rotated to align with the coastline. Hourly excursion distances were calculated in the alongshore (positive upcoast) and cross shelf (positive onshore) directions using sums of the excursions based on the 1-hr resampled currents.

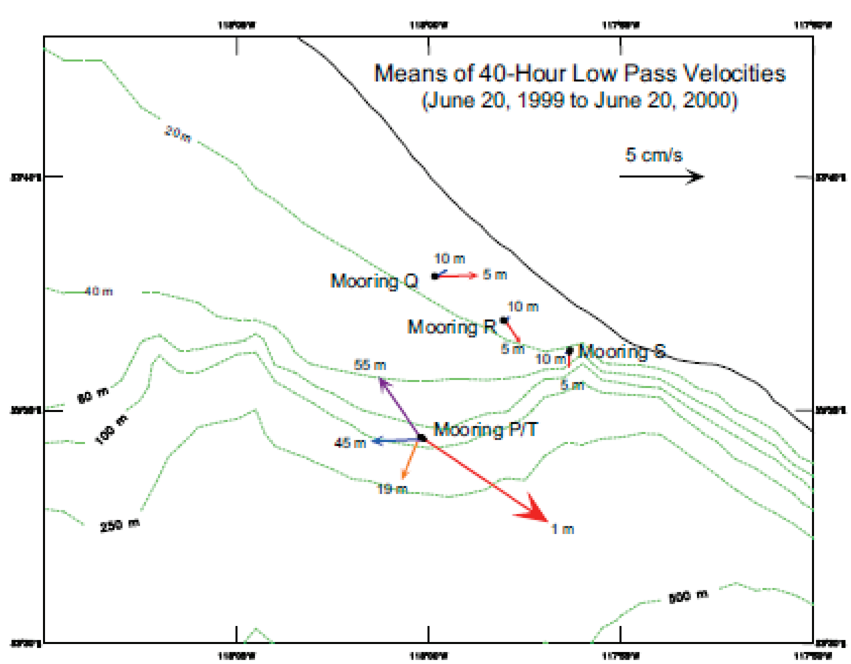

Figure 4-2. Annual mean currents at several depths at four stations near HBGS from a 1999-2000 study for the Orange County Sanitation District (SAIC 2001).

The OCSD has continued to study ocean conditions in the region near HBGS as part of long term investigation of wastewater plumes. For the *ETM* modeling presented in this report, the currents at Station M20 from December 12, 2007 to December 9, 2008 measured by an acoustic Doppler current profiler (ADCP) were used to construct a progressive vector for estimating alongshore and onshore currents (**Figure 4-3**). The instrument used was located 2.8 km (1.7 miles) southeast of Station Q at a depth of 20 m (65.6 ft) and measured magnetic east, north and up current velocities every six minutes, for one minute in 23 one meter (3.3 ft) depth bins from the bottom upward. The raw data (provided by George Robertson, Senior Scientist, OCSD) were collated into one hour averages beginning 2.1 m (6.9 ft) from the ADCP to near surface determined by the instrument depth reading times the cosine 20 degrees (skew of the ADCP beams). Station M20 is located about 3.1 km (1.9 mi) from the HBGS intake. The vectors measured by the instrument were rotated using a 12º48’ east magnetic declination and a coastwise direction of 307º to orient the upcoast flow pointing north.

The 1999–2000 progressive current vectors used in the 2003–2004 entrainment study and the 2007–2008 vectors used for this analysis are compared in **Figure 4-3**. The comparison shows that the yearly alongshore progression is similar: the water column data average from Station M20 progressed 881 km (547 miles) downcoast; the alongshore progression from Station Q (5 m [16.4 ft] subsurface) progressed 682 km (424 miles), mainly downcoast. Surface currents at Station M20 (**Figure 4-3c)** progressed twice as far as the average water column currents (**Figure 4-3b)**, and bottom currents (**Figure 4-3d)** showed offshore movement but little alongshore displacement.

The onshore progression in the 2007-2008 data was less than the 1999-2000 current progression but consistent with other stations used by OCSD. According to SAIC (2009) the average monthly near-surface currents show a predominance of downcoast flows, with only a weak reversal in the fall. Near-bottom flows in deeper water than Station M20 are upcoast most of the year, weakest in early spring, and strongest in the fall. This corresponds to the strengthening of the poleward flow of the Southern California Countercurrent in the fall and early winter, and it may also be related to strengthening and surfacing of the California Undercurrent (Hickey 1979). At mid-depths (30 m [98 ft]), the monthly mean flows are midway between those in the near-surface and near-bottom layers, with downcoast flow during the first half of the year and upcoast flow during the second half of the year. The current meters’ measurements of alongshore flows are consistent with the results of the OCSD’s Plume Tracking Model that measured plume components at distances of several kilometers upcoast and downcoast from the outfall (MEC and AOS 2001), and the Particle Tracking Model (SAIC 2003) that predicted effluent particle deposition within a narrow footprint extending up- and downcoast from the wastewater outfall, consistent with the alongshore flow directions, with only minor cross-shelf dispersion. Alongshore flows were mainly downcoast and strongest on the surface near the coast while in deeper water bottom flows showed poleward movement (**Figure 4-2**).

Source water volumes for the sampling areas were calculated from bathymetric data for the coastal areas around Huntington Beach (**Figure 4-4, Table 4-1**). These volumes were used in calculating the total number of larvae for target taxa in the sampled source water, and used with the daily volume of the desalination feedwater (575,383 m^3, 152 mgd) in calculating the daily *PE* estimates used in the *ETM* calculations. The areas of the extrapolated stations (I1 and I2) are approximately four times the area of the sampled stations. While the volume for Station I2 is approximately six times the average volume of the sampled stations, the volume of Station I1 is substantially larger because the area includes deeper depths associated with the drop-off into Newport Canyon (**Figure 4-4**).

Table 4-1. Area, volume, and average depth of HBGS source water sampling locations, including the values for the two extrapolated source water areas, I1 and I2.

Station	Area (m^2)	Volume (m^3)	Average Depth (m)
D2	3,349,340	28,487,976	8.5
D4	4,164,939	34,138,031	8.1
E	3,613,797	28,360,943	7.7
O2	2,765,512	43,697,047	15.8
O4	4,234,490	99,644,641	23.7
U2	3,211,727	21,159,762	6.2
U4	3,651,953	21,696,873	5.6
I1	13,804,831	398,613,394	28.3
I2	12,692,946	232,359,192	18.2

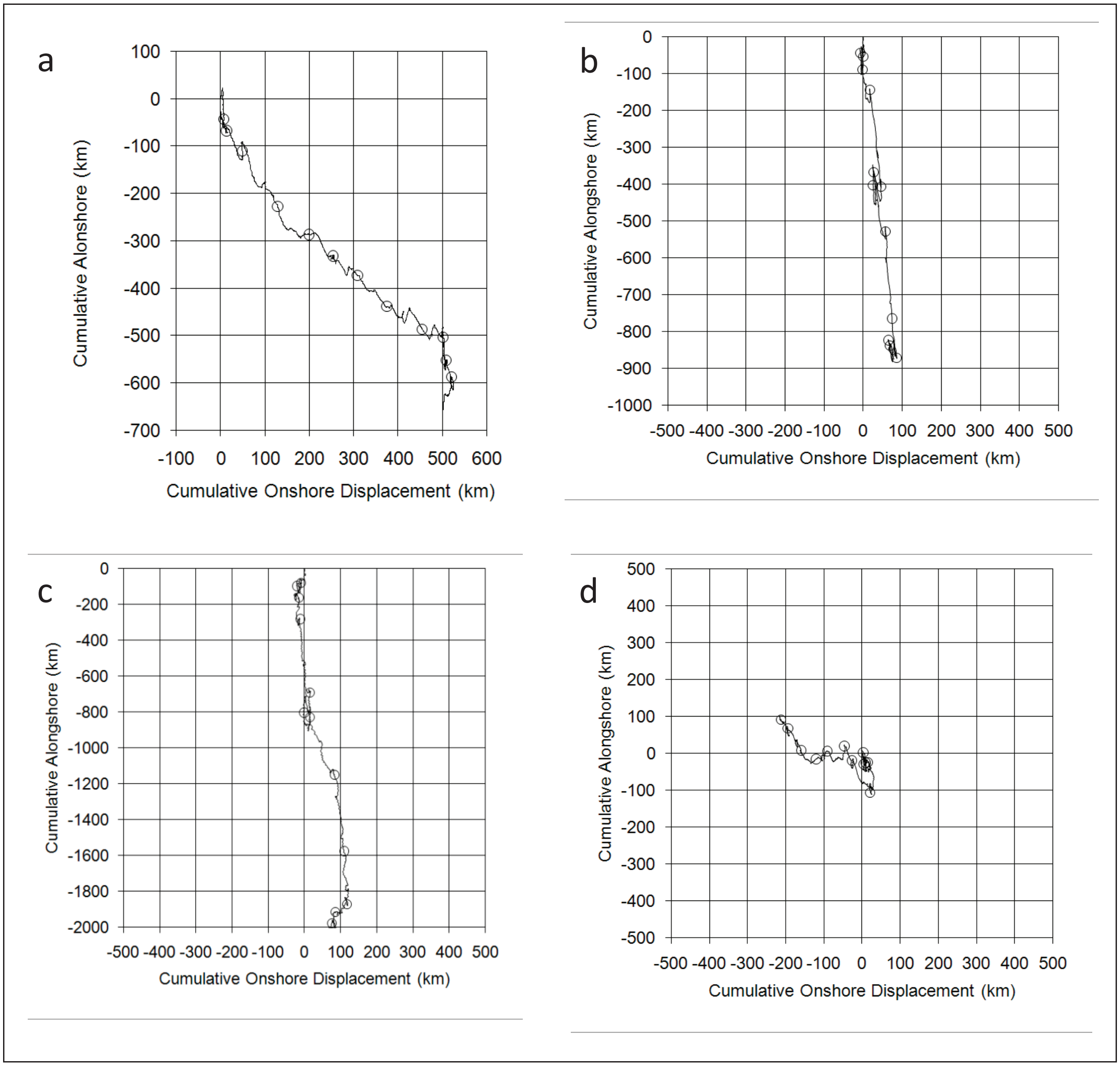

Figure 4-3. Progressive current vector diagrams for one year periods near HBGS intake. Open circles show month.

a. Current velocity measurements (averaged over three minutes) collected at 30-minute intervals from a current meter (Falmouth Scientific 2D-Acoustic Current Meter) at 5-m depth at Station Q for June 1999 through June 2000.
b. Hourly average current velocity measurements (sampled for one minute at 6-minute intervals) averaged across entire water column from a current meter (RD Instruments Acoustic Doppler Current Profiler) at Station M20 for December 2007–December 2008.
c. Hourly average current velocity measurements (sampled for one minute at 6-minute intervals) averaged over the near surface 3 m of the water column at Station M20.
d. Hourly average current velocity measurements (sampled for one minute at 6-minute intervals) averaged over the bottom 3 m of the water column at Station M20.

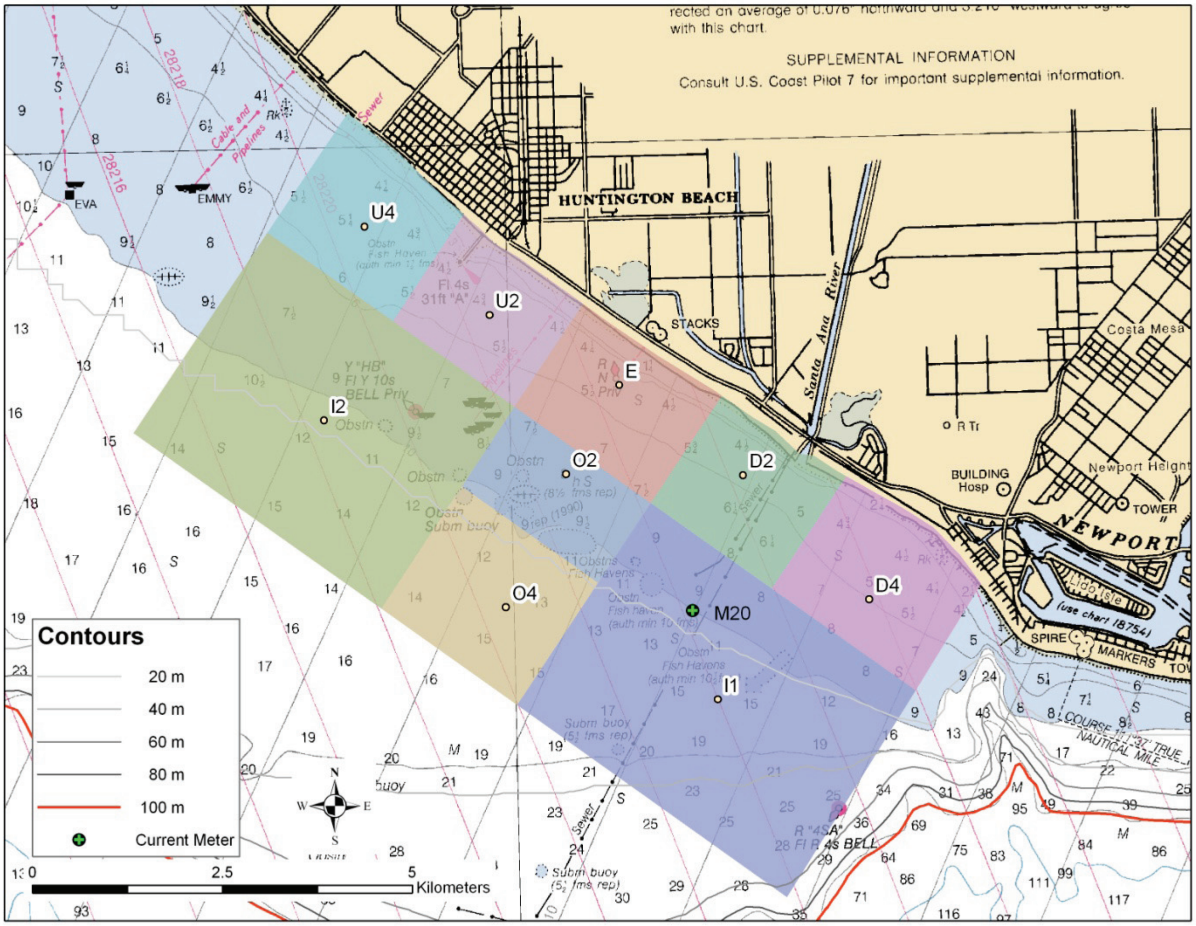

Figure 4-4. Bathymetry and areas used in calculating sampling volumes for each station used in calculating source water for *ETM* calculations. Station E designates the location where entrainment samples were collected near the intake. Currents were collected by an acoustic Doppler current profiler at station M20 in 2007-2008.

4.3 Results

The following section presents results of the AES HBGS Entrainment and Impingement Study (MBC and Tenera 2005), including data on entrainment and source water larval concentrations collected from September 2003–August 2004. Estimates of entrainment were derived from samples collected just offshore of the intake structure. Source water estimates were derived from samples collected up to four kilometers upcoast, downcoast, and offshore of the intake structure. Survey HBS026 (26–27 March 2004) was aborted due to high winds. Complete data by survey are presented in **Appendix B**.

4.3.1 Ocean Currents

Ocean currents in the Southern California Bight (SCB) are well studied (**Figure 4-5**) and the OCSD has contributed to recent knowledge about near coastal flows. In particular, SAIC (2009) completed a review of currents for the OCSD summarizing that average monthly subtidal surface currents were downcoast (**Figure 4-2**). Near-bottom flows were upcoast most of the time. Currents at mid depths (~30 m [98 ft]) flowed equally up and downcoast. Long-term mean currents effectively transport the OCSD wastewater plume. The 2001 Huntington Beach study (Hamilton 2004) illustrated stratified flows with depth.

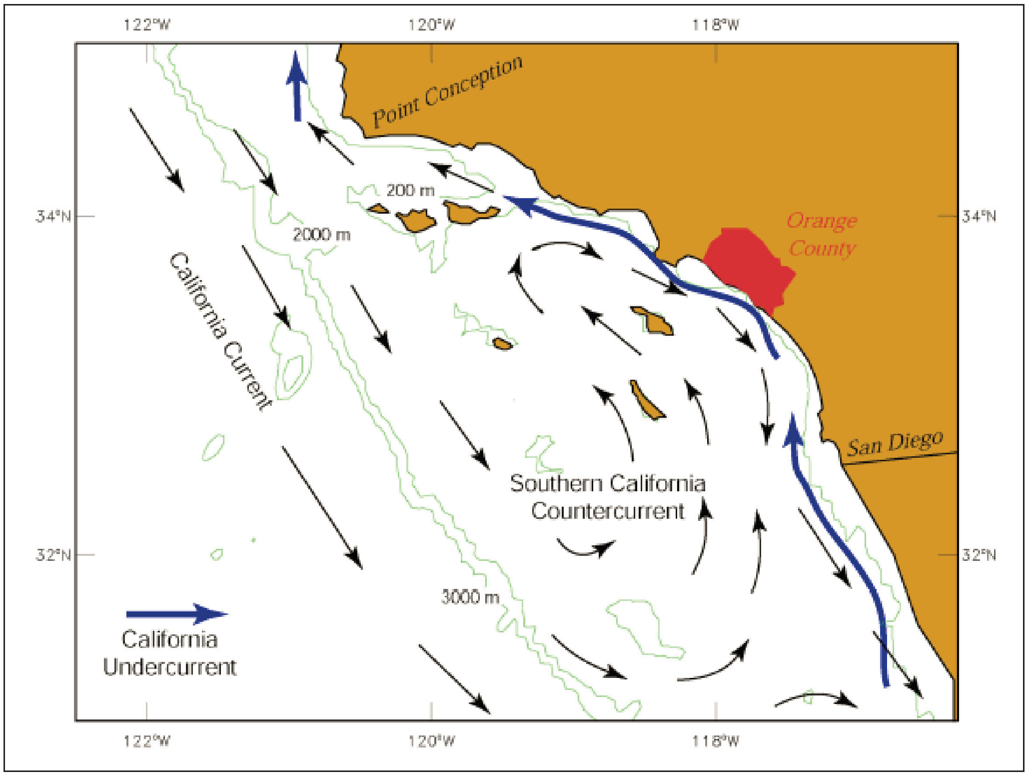

Figure 4-5. Generalized ocean circulation in the Southern California Bight from SAIC (2009) modified from Hickey (1993). HBGS is located on the coast of Orange County.

Additional findings about currents in the vicinity of HBGS (SAIC 2009) were that internal tides could not be well described and cannot be predicted though sea breeze currents and internal tides interacted at shallow depths. There were daily cycles of vertical mixing of the water column from winds that primarily affect surface currents. Stratification was seen year round at depth, with the upper waters being well mixed in the winter. Currents need to be measured since the temporal and spatial scales involved cannot be presently modeled. Near-coast, near-surface currents were downcoast, both in the 2001 current measurements from stations near HBGS and from recently deployed nearby stations, one of which was used in the present report for *ETM* calculations of larval mortality due to entrainment.

Currents measured at Station M20 from December 2007 to December 2008 generally moved in an onshore and downcoast direction (**Figure 4-4**). Researchers have consistently reported similar current patterns in the area near HBGS. Hamilton (2004) described the currents near the HBGS and found that larger-scale coastal processes influenced local current patterns more than tides and localized wind conditions. They found that, in summer 2001, currents moved predominantly in a downcoast direction over the continental shelf with maximum velocities occurring near the surface on the outer portion of the shelf (**Figure 4-6**). Currents tended to decrease as a function of proximity to the shore.

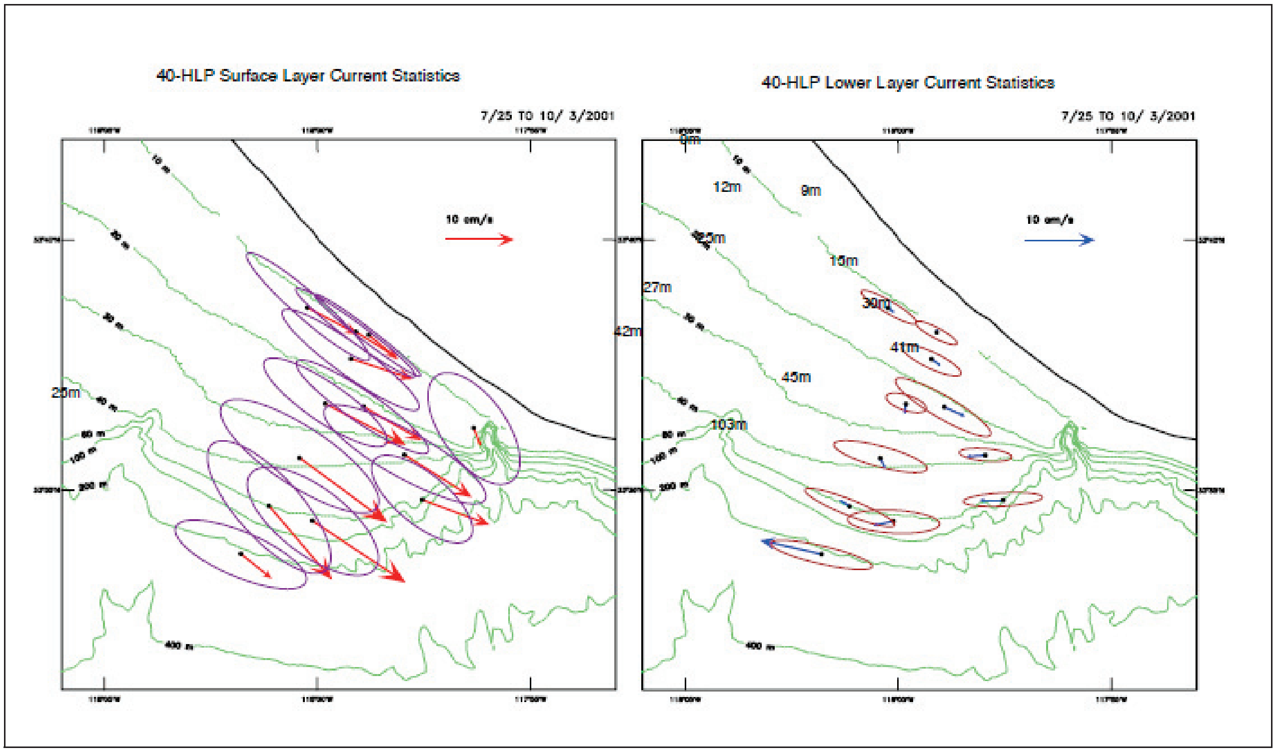

Figure 4-6. Surface currents near HBGS (1 to 6 m, left) and bottom layer (right) means and standard deviation ellipses from Hamilton (2004).

Progressive current vector data from Station M20 (**Figure 4-7**) were used in calculating the *ETM* transport model results, as described in MBC and Tenera (2005).

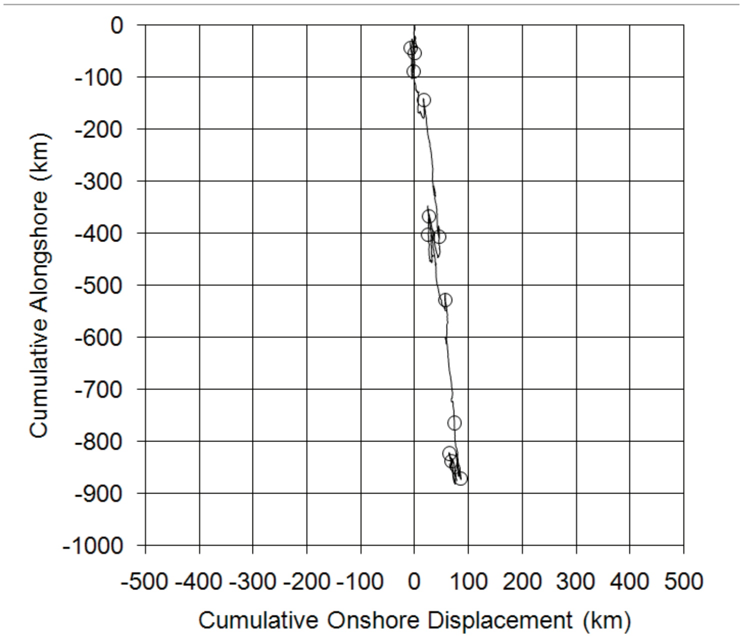

Figure 4-7. Progressive current vectors show the cumulative onshore and upcoast (alongshore) current vectors from Station M20 collected December 12, 2007 through December 9, 2008. Circles show cumulative monthly positions.

4.3.2 Cooling Water Intake Structure Entrainment Summary

A total of 6,723 fish larvae in 53 taxonomic groups was collected during the 44 entrainment surveys completed during the September 2003–August 2004 study period; 175 yolk sac/larval-post larval specimens that could not be identified were also collected (**Table 4-2**). The total estimated number of identified fish larvae entrained annually, based on a hypothetical pumping rate of 152 mgd, was 103,303,290. Ten taxa comprised approximately 91% of the total estimated annual entrainment: unidentified gobies (mainly of the genera *Clevelandia, Ilypnus*, and *Quietula* [CIQ complex]), spotfin croaker, anchovies (>95% were northern anchovy), queenfish, white croaker, salema, unidentified croakers (newly hatched larvae of several species), combtooth blennies, black croaker, and diamond turbot. The life histories and potential impacts from entrainment on the local populations of these taxa and California halibut, which is an important recreational and commercial species that ranked 11th in total estimated annual entrainment, are analyzed in greater detail in this report (see Section 4.3.4–*Results by Species*). Of the five target invertebrate taxa included in the study (cancrid crab megalops, market squid postlarvae, Pacific sand crab, California spiny lobster, and ridgeback rock shrimp) only Pacific sand crab and cancrid crabs were found in the entrainment samples (**Table 4-3**). Pacific sand crab zoeae comprised approximately 98% of the total annual estimated entrainment of target invertebrates. Almost all of the Pacific sand crab larvae collected were in the earliest stages of their larval development (zoea Stage I); only two megalopal stage larvae were collected from entrainment samples and none were collected from source water samples. Sampling results are presented for cancrid crabs, but no assessments of potential entrainment impacts were conducted for Pacific sand crab because of the low numbers collected and absence of megalops in the source water samples.

The number of individual fish taxa increased during the study with greatest numbers of taxa occurring in summer 2004, from an average of approximately eight taxa per survey from September through February to 18 taxa per survey in summer 2004, including a survey in late July when over 30 taxa were collected (**Figure 4-8**). The greatest overall larval fish abundances occurred in late summer 2004 when concentrations were approximately five times greater than earlier months (**Figure 4-9**). Although gobies and anchovies were abundant throughout the sampling period, high concentrations of spotfin croaker, salema, and queenfish contributed to peak abundances in August 2004. Low concentrations of larvae were measured during some surveys in early February and early March, although abundances generally increased through spring when many fishes start reproducing.

Entrainment samples were characterized by large numbers of gobies, blennies, and several other fishes common in bay environments whose larvae were probably exported into the open ocean by tidal currents from estuarine spawning areas upcoast and downcoast of the HBGS. Some commercially and recreationally important taxa such as California halibut, white seabass, and rockfishes comprised a smaller percentage of the total number of taxa entrained, but others, including northern anchovy and several croaker species, comprised nearly 50% of the total fish larvae collected (**Table 4-2**).

Larval fish concentrations at the entrainment station were relatively similar from the onset of the study in September 2003 through April 2004 (**Figure 4-9**). Concentrations increased in spring and summer (May through July 2004), corresponding to higher concentrations of CIQ gobies, white croaker, combtooth blennies, and several other taxa. Highest concentrations at the entrainment station were measured in late August 2004, and corresponded to high concentrations (greater than 1,800 larvae per 1,000 m^3) of spotfin croaker. Larval fish concentrations measured at the entrainment station were almost always higher at nighttime than during daytime (**Figure 4-10**).

Table 4-2. Estimated annual entrainment (152 mgd) of larval fishes collected during 44 entrainment surveys from September 2003 through August 2004.

	Taxon	Common Name	Estimated Annual Entrainment	Sample Count	Percent of Total Est. Annual Entrain.	Mean Conc. (#/1,000 m^3)
1	Gobiidae (CIQ complex)	gobies	33,927,750	2,484	32.84	151.56
2	*Roncador stearnsi*	spotfin croaker	20,896,741	912	20.23	53.07
3	Engraulidae	anchovies	16,293,995	1,209	15.77	74.46
4	*Seriphus politus*	queenfish	5,339,449	306	5.17	18.17
5	*Genyonemus lineatus*	white croaker	5,284,106	446	5.12	28.14
6	*Xenistius californiensis*	salema	3,506,783	153	3.39	7.70
7	Sciaenidae	croaker	3,158,365	244	3.06	14.73
8	*Hypsoblennius* spp.	blennies	2,148,242	166	2.08	10.28
9	*Cheilotrema saturnum*	black croaker	2,137,034	96	2.07	5.41
10	*Hypsopsetta guttulata*	diamond turbot	1,631,863	87	1.58	5.28
11	*Paralichthys californicus*	California halibut	1,505,361	98	1.46	6.40
12	Atherinopsidae	silverside	1,095,549	97	1.06	5.98
13	*Menticirrhus undulatus*	California corbina	842,271	43	0.82	2.33
14	*Paralabrax* spp.	sand bass	837,568	48	0.81	2.93
15	*Citharichthys* spp.	sanddabs	573,705	31	0.56	2.15
16	*Hypsypops rubicundus*	garibaldi	486,570	43	0.47	2.44
17	*Oxyjulis californica*	senorita	356,900	27	0.35	1.66
18	*Sphyraena argentea*	California barracuda	339,708	14	0.33	0.79
19	Pleuronectidae	flounders	294,532	17	0.29	1.02
20	*Umbrina roncador*	yellowfin croaker	288,682	24	0.28	1.63
21	*Gillichthys mirabilis*	longjaw mudsucker	250,240	20	0.24	1.29
22	*Lepidogobius lepidus*	bay goby	205,031	18	0.20	1.16
23	Syngnathidae	pipefishes	177,332	17	0.17	0.91
24	*Leptocottus armatus*	Pacific staghorn sculpin	175,284	16	0.17	0.97
25	*Pleuronichthys ritteri*	spotted turbot	168,477	12	0.16	0.75
26	*Triphoturus mexicanus*	Mexican lampfish	160,792	8	0.16	0.51
27	*Acanthogobius flavimanus*	yellowfin goby	156,674	15	0.15	0.88
28	*Diaphus theta*	California headlight fish	145,786	11	0.14	0.63
29	Myctophidae	lanternfishes	126,990	6	0.12	0.39
30	Haemulidae	grunts	110,393	5	0.11	0.28
31	*Atractoscion nobilis*	white seabass	104,123	5	0.10	0.29
32	*Gibbonsia* spp.	clinid kelpfishes	102,509	10	0.10	0.55
33	*Pleuronichthys verticalis*	hornyhead turbot	59,502	3	0.06	0.17
34	*Sardinops sagax*	Pacific sardine	49,984	4	0.05	0.25
35	*Peprilus simillimus*	Pacific butterfish	41,414	2	0.04	0.14
36	*Semicossyphus pulcher*	California sheephead	38,741	2	0.04	0.13
37	*Stenobrachius leucopsarus*	northern lampfish	33,311	3	0.03	0.21
38	Labrisomidae	labrisomid kelpfishes	32,668	3	0.03	0.18
39	*Halichoeres semicinctus*	rock wrasse	29,184	1	0.03	0.06
40	Paralichthyidae	lefteye flounders & sanddabs	28,540	2	0.03	0.12
41	*Medialuna californiensis*	halfmoon	23,326	2	0.02	0.13

42	*Scomber japonicus*	Pacific mackerel	18,289	2	0.02	0.10
43	Scorpaenidae	scorpionfishes	15,130	1	0.01	0.09
44	*Symphurus atricauda*	California tonguefish	12,695	1	0.01	0.07

(table continued)

Table 4-2 (continued). Estimated annual entrainment (152 mgd) of larval fishes collected during 44 entrainment surveys from September 2003 through August 2004.

	Taxon	Common Name	Estimated Annual Entrainment	Sample Count	Percent of Total Est. Annual Entrain.	Mean Conc. (#/1,000 m^3)
45	*Strongylura exilis*	California needlefish	12,183	1	0.01	0.07
46	*Oxylebius pictus*	painted greenling	12,079	1	0.01	0.07
47	*Typhlogobius californiensis*	blind goby	11,086	1	0.01	0.06
48	*Merluccius productus*	Pacific hake	10,179	1	0.01	0.06
49	*Coryphopterus nicholsi*	blackeye goby	9,954	1	0.01	0.06
50	Agonidae	poachers	9,239	1	0.01	0.05
51	*Ruscarius creaseri*	roughcheek sculpin	9,238	1	0.01	0.05
52	Pleuronectiformes	flatfishes	9,052	1	0.01	0.05
53	Cottidae	sculpins	8,691	1	0.01	0.05
			103,303,290	**6,723**	**100.00**	**406.91**
	larvae, unidentified yolk sac	unid. yolk sac larvae		136		
	larval/post-larval fish unid.	larval/post-larval fish unid.		39		
				175		

Table 4-3. Estimated annual entrainment (152 mgd) of larval invertebrates (target taxa only) collected during 44 entrainment surveys from September 2003 through August 2004.

	Taxon	Common Name	Estimated Annual Entrainment	Sample Count	Percent of Total Est. Annual Entrain.	Mean Conc. (#/1,000 m^3)
1	*Emerita analoga* (zoea)	Pacific sand crab	139,650,271	10,399	98.35	658.95
2	*Metacarcinus anthonyi* (megalops)	yellow crab	1,922,088	77	1.35	4.68
3	*Metacarcinus gracilis* (megalops)	graceful crab	391,174	31	0.28	1.97
4	*Romaleon antennarius* (megalops)	Pacific rock crab	*	18		1.15
5	*Cancer productus* (megalops)	red rock crab	*	3		0.18
6	*Emerita analoga* (megalops)	Pacific sand crab	20,924	2	0.02	0.17
7	Cancridae (megalops)	cancer crabs	*	2		0.11
8	Cancridae	cancer crabs	10,758	1	0.01	0.06
			141,995,215	**10,533**	**100.00**	**667.27**

* total entrainment estimate included with *Metacarcinus anthonyi.*

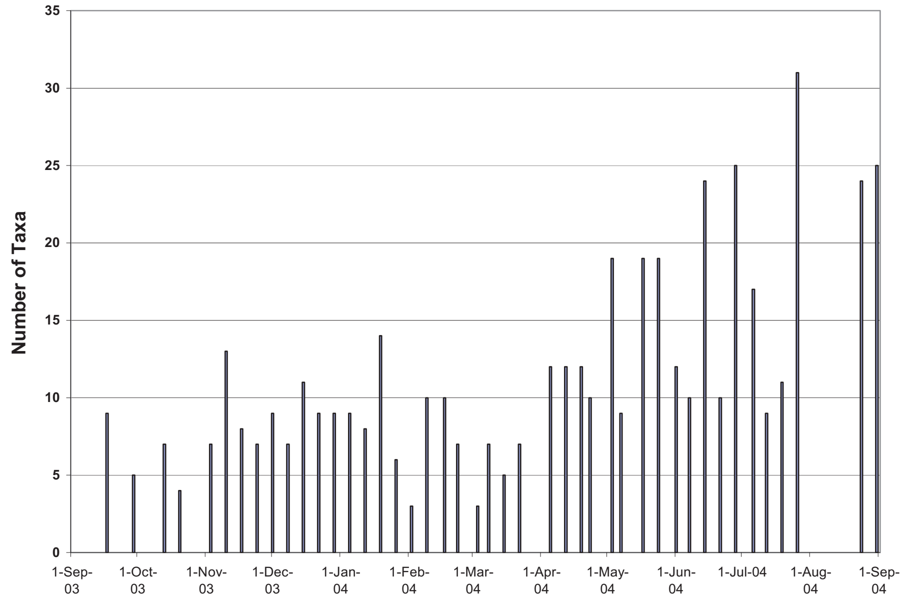

Figure 4-8. Total number of taxa collected per survey at Station E from September 2003 through August 2004.

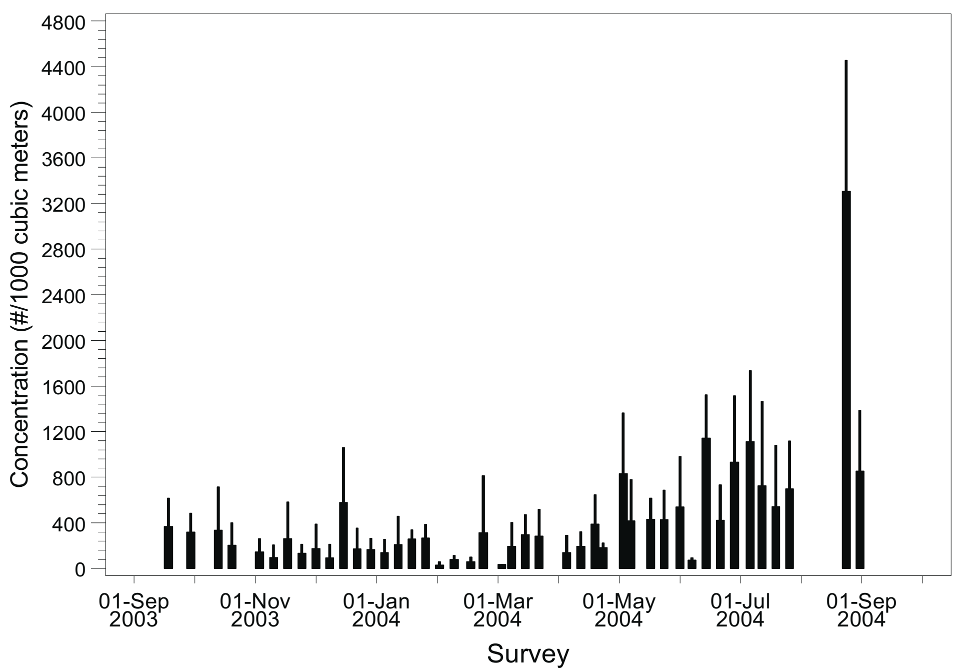

Figure 4-9. Mean concentration (#/1,000 m^3) and standard error for all larval fishes collected at Station E from September 2003 through August 2004.

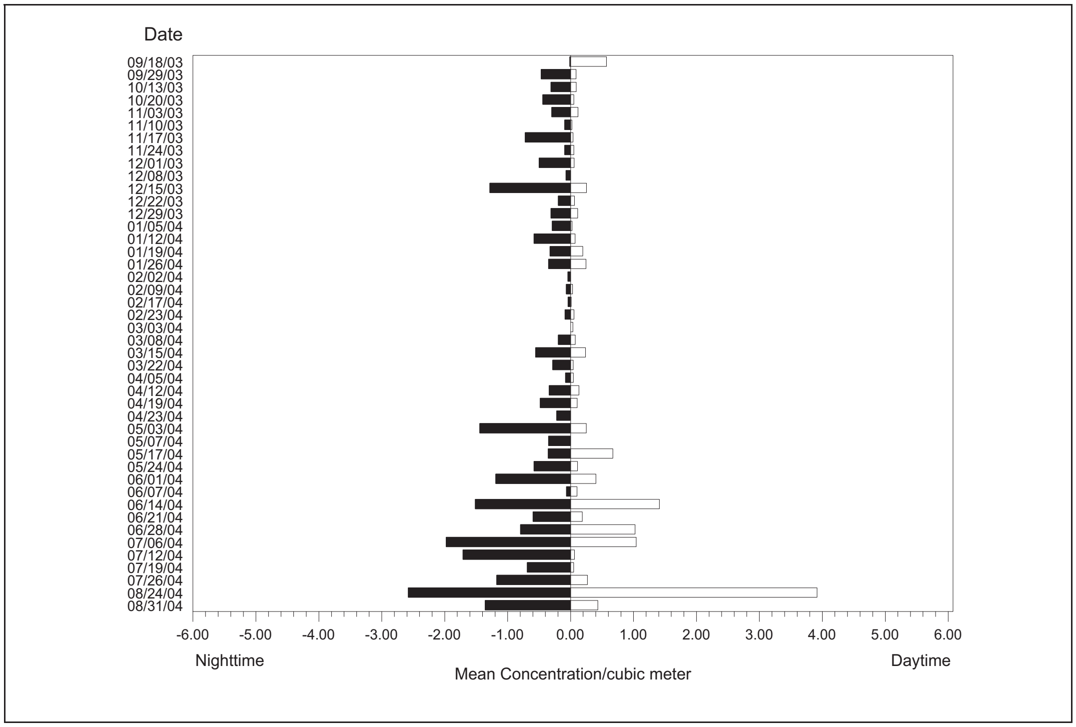

Figure 4-10. Mean concentration (#/1.0 m^3) of all larval fishes collected at HBGS entrainment Station E at nighttime (black) and daytime (white).

4.3.3 Source Water Summary

A total of 14,328 fish larvae in 79 taxonomic groups was collected during the 12 source water surveys completed during the September 2003–August 2004 study period (**Table 4-4**); an additional 211 unidentified yolk sac/larval/post-larval specimens were also collected. Eleven taxa comprised nearly 90% of the total larvae collected: unidentified gobies (36.8%; mainly of the genera *Clevelandia, Ilypnus*, and *Quietula* [CIQ complex]), anchovies, queenfish, white croaker, unidentified croakers (newly hatched larvae of several species), combtooth blennies, sand bass, California halibut, silversides, Pacific sardine, and California barracuda. During the 12 source water surveys there were 23 additional taxa collected at stations other than the single entrainment station (Station E) during 44 entrainment surveys. Similar to the entrainment station concentrations, the lowest larval concentrations in the source water were measured in winter and the highest concentrations in summer (**Figure 4-11**).

The composition of the target invertebrates collected at the source water stations was similar to the entrainment samples with Pacific sand crab larvae comprising nearly 95% of the target invertebrates collected (**Table 4-5**). Almost all of the Pacific sand crab larvae collected were in the earliest stage of larval development (zoea Stage I); only two megalopal stage larvae were collected at the entrainment station during one of the paired entrainment-source water surveys. In addition to cancrid crab larvae, one California spiny lobster puerulus stage larva was collected.

Concentrations of the CIQ goby complex, anchovies, and white croaker, three of the most abundant fish taxa, varied spatially among the seven sampling stations and temporally among months. The CIQ goby complex was generally more abundant at the inshore stations in all months and also tended to be more abundant at the intake (entrainment) and downcoast stations. Anchovies did not show a strong distributional trend among stations whereas white croaker was more abundant offshore in summer. The monthly spatial distribution of HBGS source water larvae was presented in greater detail in MBC and Tenera (2007).

Table 4-4. Larval fishes collected during twelve source water surveys from September 2003 through August 2004. Sample totals and mean concentrations were calculated from all seven stations, which includes entrainment Station E.

	Taxon	Common Name	Sample Count	Percent of Total Number Collected	Cumul. Percent	Mean Conc. (#/1,000 m^3)
1	Gobiidae (CIQ complex)	gobies	5,275	36.82	36.82	169.83
2	Engraulidae	anchovies	2,525	17.62	54.44	81.41
3	*Seriphus politus*	queenfish	1,418	9.90	64.34	45.85
4	*Genyonemus lineatus*	white croaker	1,239	8.65	72.98	39.46
5	Sciaenidae	croakers	541	3.78	76.76	17.92
6	*Hypsoblennius* spp.	blennies	439	3.06	79.82	13.82
7	*Paralabrax* spp.	sand bass	408	2.85	82.67	13.61
8	*Paralichthys californicus*	California halibut	399	2.78	85.46	12.70
9	Atherinopsidae	silversides	333	2.32	87.78	10.55
10	*Sardinops sagax*	Pacific sardine	147	1.03	88.81	4.91
11	*Sphyraena argentea*	California barracuda	145	1.01	89.82	4.73
12	*Chromis punctipinnis*	blacksmith	166	1.16	90.98	4.59
13	*Citharichthys* spp.	sanddabs	141	0.98	91.96	4.53
14	*Hypsopsetta guttulata*	diamond turbot	122	0.85	92.81	3.96
15	Ophidiidae	cusk-eels	99	0.69	93.50	3.26
16	*Lepidogobius lepidus*	bay goby	86	0.60	94.10	2.73
17	*Pleuronichthys ritteri*	spotted turbot	68	0.47	94.58	2.10
18	*Pleuronichthys verticalis*	hornyhead turbot	65	0.45	95.03	2.07
19	*Cheilotrema saturnum*	black croaker	61	0.43	95.46	1.90
20	*Xenistius californiensis*	salema	50	0.35	95.81	1.75
21	*Typhlogobius californiensis*	blind goby	56	0.39	96.20	1.73
22	*Oxyjulis californica*	senorita	51	0.36	96.55	1.64
23	*Roncador stearnsi*	spotfin croaker	53	0.37	96.92	1.62
24	*Gillichthys mirabilis*	longjaw mudsucker	40	0.28	97.20	1.28
25	Pleuronectidae	flounders	41	0.29	97.49	1.25
26	*Leptocottus armatus*	Pacific staghorn sculpin	28	0.20	97.68	0.91
27	*Acanthogobius flavimanus*	yellowfin goby	23	0.16	97.84	0.78
28	*Icelinus* spp.	sculpins	25	0.17	98.02	0.75
29	*Gibbonsia* spp.	clinid kelpfishes	21	0.15	98.16	0.64
30	*Xystreurys liolepis*	fantail sole	20	0.14	98.30	0.62
31	*Triphoturus mexicanus*	Mexican lampfish	19	0.13	98.44	0.62
32	*Hypsypops rubicundus*	garibaldi	20	0.14	98.58	0.60
33	*Syngnathus* spp.	pipefishes	20	0.14	98.72	0.58
34	*Menticirrhus undulatus*	California corbina	14	0.10	98.81	0.46
35	*Atractoscion nobilis*	white seabass	14	0.10	98.91	0.43
36	*Gobiesocidae*	clingfishes	12	0.08	98.99	0.39
37	*Semicossyphus pulcher*	California sheephead	13	0.09	99.09	0.37
38	*Sebastes* spp.	rockfishes	11	0.08	99.16	0.36
39	Labrisomidae	labrisomid kelpfishes	9	0.06	99.23	0.29
40	*Stenobrachius leucopsarus*	northern lampfish	9	0.06	99.29	0.27
41	*Peprilus simillimus*	Pacific butterfish	7	0.05	99.34	0.26
42	Paralichthyidae	flounders & sanddabs	8	0.06	99.39	0.26
43	*Hippoglossina stomata*	bigmouth sole	7	0.05	99.44	0.24

(table continued)

Table 4-4 (continued). Larval fishes collected during twelve source water surveys from September 2003 through August 2004. Sample totals and mean concentrations were calculated from all seven stations, which includes entrainment Station E.

	Taxon	Common Name	Sample Count	Percent of Total Number Collected	Cumul. Percent	Mean Conc. (#/1,000 m^3)
44	*Umbrina roncador*	yellowfin croaker	7	0.05	99.49	0.22
45	*Ruscarius creaseri*	roughcheek sculpin	6	0.04	99.53	0.19
46	*Symphurus atricauda*	California tonguefish	6	0.04	99.57	0.18
47	*Coryphopterus nicholsi*	blackeye goby	5	0.03	99.61	0.16
48	*Diaphus theta*	California headlight fish	5	0.03	99.64	0.16
49	Haemulidae	grunts	5	0.03	99.68	0.16
50	*Merluccius productus*	Pacific hake	5	0.03	99.71	0.15
51	Myctophidae	lanternfishes	4	0.03	99.74	0.14
52	*Halichoeres semicinctus*	rock wrasse	3	0.02	99.76	0.11
53	*Etrumeus teres*	round herring	3	0.02	99.78	0.10
54	*Medialuna californiensis*	halfmoon	3	0.02	99.80	0.09
55	Labridae	wrasses	2	0.01	99.82	0.07
56	*Lythrypnus* spp.	gobies	3	0.02	99.84	0.07
57	Cottidae	sculpins	2	0.01	99.85	0.06
58	Kyphosidae	sea chubs	2	0.01	99.87	0.06
59	*Oxylebius pictus*	painted greenling	2	0.01	99.88	0.06
60	Hexagrammidae	greenlings	2	0.01	99.90	0.06
61	*Artedius lateralis*	smoothhead sculpin	1	0.01	99.90	0.04
62	*Girella nigricans*	opaleye	1	0.01	99.91	0.04
63	*Anisotremus davidsonii*	sargo	1	0.01	99.92	0.04
64	*Scorpaenichthys marmoratus*	cabezon	1	0.01	99.92	0.04
65	*Parophrys vetulus*	English sole	1	0.01	99.93	0.03
66	*Aulorhynchus flavidus*	tubesnout	1	0.01	99.94	0.03
67	*Zaniolepis* spp.	combfishes	1	0.01	99.94	0.03
68	*Artedius* spp.	sculpins	1	0.01	99.95	0.03
69	Pleuronectiformes	flatfishes	1	0.01	99.96	0.03
70	Agonidae	poachers	1	0.01	99.97	0.03
71	Scorpaenidae	scorpionfishes	1	0.01	99.97	0.03
72	Chaenopsidae	tube blennies	1	0.01	99.98	0.03
73	Scombridae	mackerels & tunas	1	0.01	99.99	0.02
74	Clupeiformes	herrings and anchovies	1	0.01	99.99	0.02
75	Pomacentridae	damselfishes	1	0.01	100.00	0.02
			14,328			**460.52**
	larvae, unidentified yolk sac	unidentified yolk sac larvae	168			
	larval/post-larval fish unid.	larval fishes	43			
			211			

Table 4-5. Larval invertebrates (target taxa only) collected during twelve source water surveys from September 2003 through August 2004.

	Taxon	Common Name	Sample Count	Percent of Total Number Collected	Cumul. Percent	Mean Conc. (#/1,000 m^3)
1	*Emerita analoga* (zoea)	Pacific sand crab	5,476	94.54	94.54	173.26
2	*Metacarcinus gracilis* (megalops)	graceful crab	107	1.85	96.39	3.48
3	*Metacarcinus anthonyi* (megalops)	yellow crab	106	1.83	98.22	3.41
4	*Romaleon antennarius* (megalops)	Pacific rock crab	92	1.59	99.81	2.96
5	Cancridae (megalops)	cancer crabs	4	0.07	99.88	0.11
6	*Cancer productus* (megalops)	red rock crab	3	0.05	99.93	0.10
7	Cancridae	cancer crabs	3	0.05	99.98	0.09
8	*Panulirus interruptus* (puerulus)	California spiny lobster	1	0.02	100.00	0.03
			5,792			**183.44**

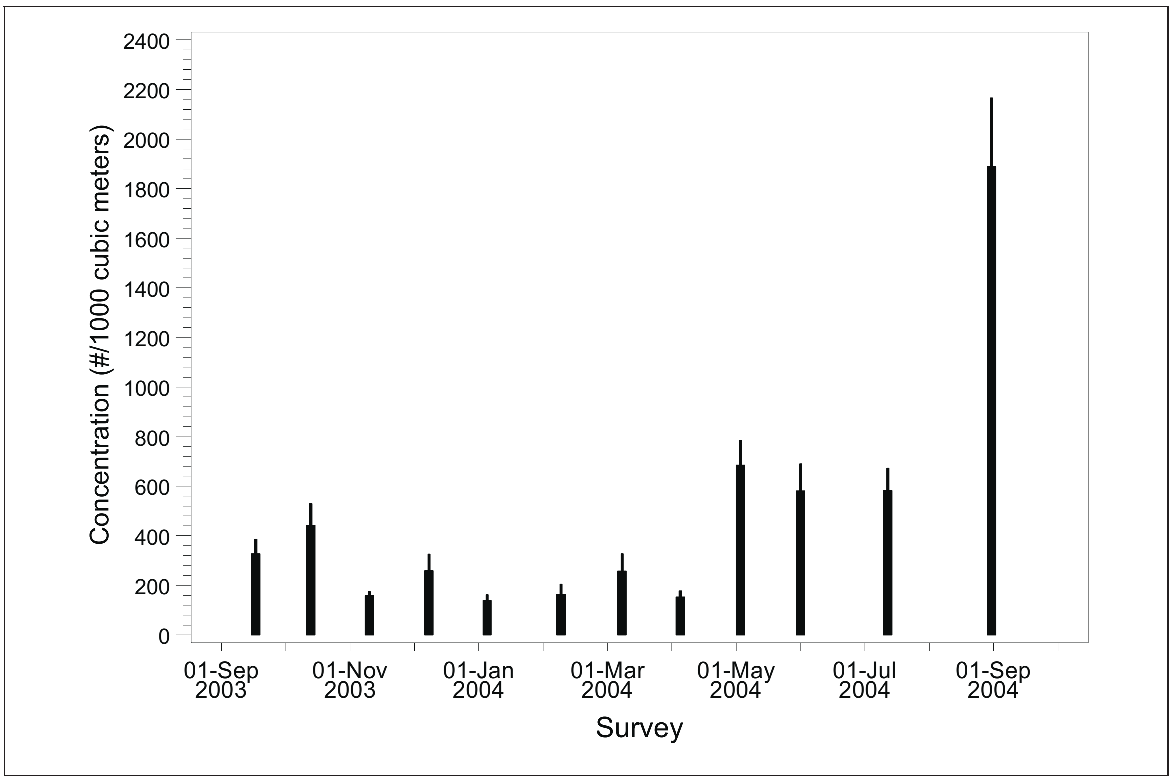

Figure 4-11. Mean concentration (#/1,000 m^3) and standard error for all larval fishes collected at HBGS source water stations (D2, D4, E, U2, U4, O2, O4) from September 2003 through August 2004.

4.3.4 Entrainment Results by Species

Based on their estimated annual entrainment, the 10 larval fish taxa that comprised the approximately 89% of estimated annual entrainment were selected for detailed analysis. This included CIQ gobies, spotfin croaker, anchovies, queenfish, white croaker, salema, combtooth blennies, black croaker, diamond turbot, and California halibut. Rock crab megalops were the only target invertebrate taxon collected in large enough abundances to be assessed for potential entrainment impacts.

4.3.4.1 Unidentified Gobies: CIQ Goby Complex

Most adult gobies are small (<10 cm [3.9 in]) and inhabit bays, estuaries, lagoons, and nearshore open coastal waters (Allen 1985, Moser 1996). Marine gobies occupy a variety of habitats, including mudflats and reefs. Many of the soft-bottom species live in burrows where they shelter from predators, escape desiccation during low tides, and brood eggs (Brothers 1975).

Larval gobiids are distinctive and unlikely to be confused with other larval fishes, but positive identification of larval gobies to the species level based on pigmentation characteristics remains difficult. Three co-occurring species cannot be differentiated with certainty during early larval stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) (Moser 1996). All three are considered common in southern California (Miller and Lea 1972), and arrow goby is common in Talbert Marsh (Gorman et al. 1990). These three species were combined into the CIQ goby complex for analysis. Descriptions of the life histories of arrow, cheekspot, and shadow goby were compiled from Brothers (1975) and were used to parameterize the analysis models.

4.3.4.1.1 Reproduction, Age, and Growth

Arrow goby mature at approximately one year post-settlement, but cheekspot and shadow gobies mature at about three years (Brothers 1975). Gobies are oviparous, and the demersal eggs are elliptical, typically adhesive, and about 2–4 mm (0.08–0.16 in) long (Moser 1996). Primary spawning activity of arrow goby occurs from March through June (Prasad 1958), but protracted spawning can occur in arrow, shadow, and cheekspot gobies (Brothers 1975). High abundances of arrow goby larvae in southern California were seen from March to September corresponding to the timing of settlement (Brothers 1975). Settlement of shadow and cheekspot gobies typically occurs in late summer and early fall (Brothers 1975).

Arrow goby grows faster than cheekspot and shadow gobies (Brothers 1975). After maturity, however, growth rate in the arrow goby declines. Shadow and cheekspot gobies settle at smaller sizes and grow more slowly, but the growth rate is relatively constant for their entire life. Shadow and cheekspot gobies can live up to four years, while arrow goby rarely live longer than three years. In southern California, arrow goby reaches maximum lengths of 32 mm SL (1.25 in), shadow goby 40 mm SL (1.57 in), and cheekspot goby 46 mm SL (1.8 in) (Brothers 1975). Brothers (1975) estimated that the population mortality of arrow goby in Mission Bay following settlement was 91% in the first year and nearly 99% thereafter. He also calculated that the annual mortality rates after settlement were 66–74% for cheekspot goby, and 62–69% for shadow goby.

CIQ goby larvae hatch at a size of 2–3 mm (0.08-0.12 in) (Moser 1996). Using data available in Brothers (1975), the average growth rate of this group was estimated at 0.16 mm/day (0.006 in/day) for the 60-day period from hatching until settlement. Brothers (1975) estimated that larval mortality for this period was 98.3% for arrow goby, 98.6% for cheekspot, and 99.2% for shadow goby. Based on the total mortality for this period, average daily survival was calculated at 0.93 for the three species. Juveniles settle to the bottom at a size of about 10–15 mm (0.39-0.59 in) SL (Moser 1996).

4.3.4.1.2 Population Trends and Fishery

There is no recreational or commercial fishery for gobies in southern California and no population estimates or trends are available for southern California gobies. Densities of arrow goby have been reported for two locations within 22 km (13.7 mi) of the HBGS. During the final year of a five-year monitoring project, MBC (2003b) reported seasonal densities of 0.72 to 4.53 individuals/m^2 at the Golden Shore Marine Reserve. The study site was a created wetland at the mouth of the Los Angeles River. At Anaheim Bay, MacDonald (1975) reported densities of arrow goby of 4 to 5 individuals/m^2, though investigation of individual burrows resulted in much higher densities (up to 20 fish/m^2) in some locations.

4.3.4.1.3 Sampling Results

The CIQ goby complex was the most abundant taxon collected during the 2003–2004 study. They comprised nearly 32.8% of the total estimated annual number of entrained larval fishes (**Table 4-2**). CIQ gobies were also the most abundant taxon collected at the source water stations (**Table 4-3**). CIQ gobies were abundant at the entrainment station throughout the sampling period but were in highest abundance during July (**Figure 4-12a**). Mean abundance in the source water samples was highest in the September survey and lowest during the November survey (**Figure 4-12b**). The number and concentration of larval CIQ gobies collected during each entrainment and source water survey were presented in MBC and Tenera (2005).

The length frequency distribution of measured CIQ gobies (**Figure 4-13**) illustrates that the majority of the larvae were recently hatched based on the reported hatch length of 2–3 mm (0.08–0.12 in) (Moser 1996). The mean, maximum, and minimum sizes for the 1,010 measurements were 3.6, 21.3, and 1.5 mm (0.14, 0.84, 0.06 in), respectively. A larval growth rate of 0.16 mm/day (0.006 in/day) was estimated from Brothers (1975) using his reported transformation lengths for the three species and an estimated transformation age of 60 days. Statistical analysis of a random sample of 200 of the measured larvae was used to estimate a mean length of 3.5 mm (0.14 in), a hatch length of 2.3 mm (0.09 in), and the length at the 95th percentile of 7.2 mm (0.28 in). The difference in the lengths at hatching and the 95th percentile of the measurements was used with the larval growth rate to estimate that the larvae were exposed to entrainment for a period of 31 days.

4.3.4.1.4 Impact Assessment

The following sections present the results for demographic and empirical transport modeling of the effects of the proposed desalination water intakes. A comprehensive comparative study of the three goby species in the CIQ complex by Brothers (1975) provided the necessary life history information for the *FH* demographic model. The estimated mean entrainment concentration per survey was variable, ranging from 2.6 to about 490 CIQ goby larvae per 1,000 m^3 (**Figure 4-12a**).

Fecundity Hindcasting (*FH*)

The annual entrainment estimate for CIQ gobies was used to estimate the number of females at the age of maturity needed to produce the number of larvae entrained during their lifetime. No estimates of egg survival for gobies were available, but because gobies deposit demersal egg masses (Wang 1986) and exhibit parental care, usually provided by the adult male, egg survival is generally high and was conservatively assumed to be 100%. Estimates of larval survival for the three species from Brothers (1975) were used to compute an average daily survival of 0.93. A larval growth rate of 0.16 mm/day (0.006 in/day) was estimated from transformation lengths reported by Brothers (1975) for the three species and an estimated transformation age of 60 days. The mean length and the estimated hatch length based on measurements of a random sample of 200 of the measured larvae were used with the calculated growth rate to estimate that the mean age at entrainment was 7.9 days. Survival to the average age at entrainment was then estimated as $0.93^{7.9} = 0.57$. A survivorship table was constructed using data from Brothers (1975) and was used to estimate a total lifetime fecundity of 1,400 eggs (**Table 4-6**). The age when 50% of the female population was reproductive averaged 1.67 years.

The estimated number of adult females whose lifetime reproductive output would be entrained annually through the desalination water intakes was 42,709 (**Table 4-7**). The results show that the variation in our estimate of entrainment had much less of an effect on the range of the *FH* estimate than the life history parameters used in the model.

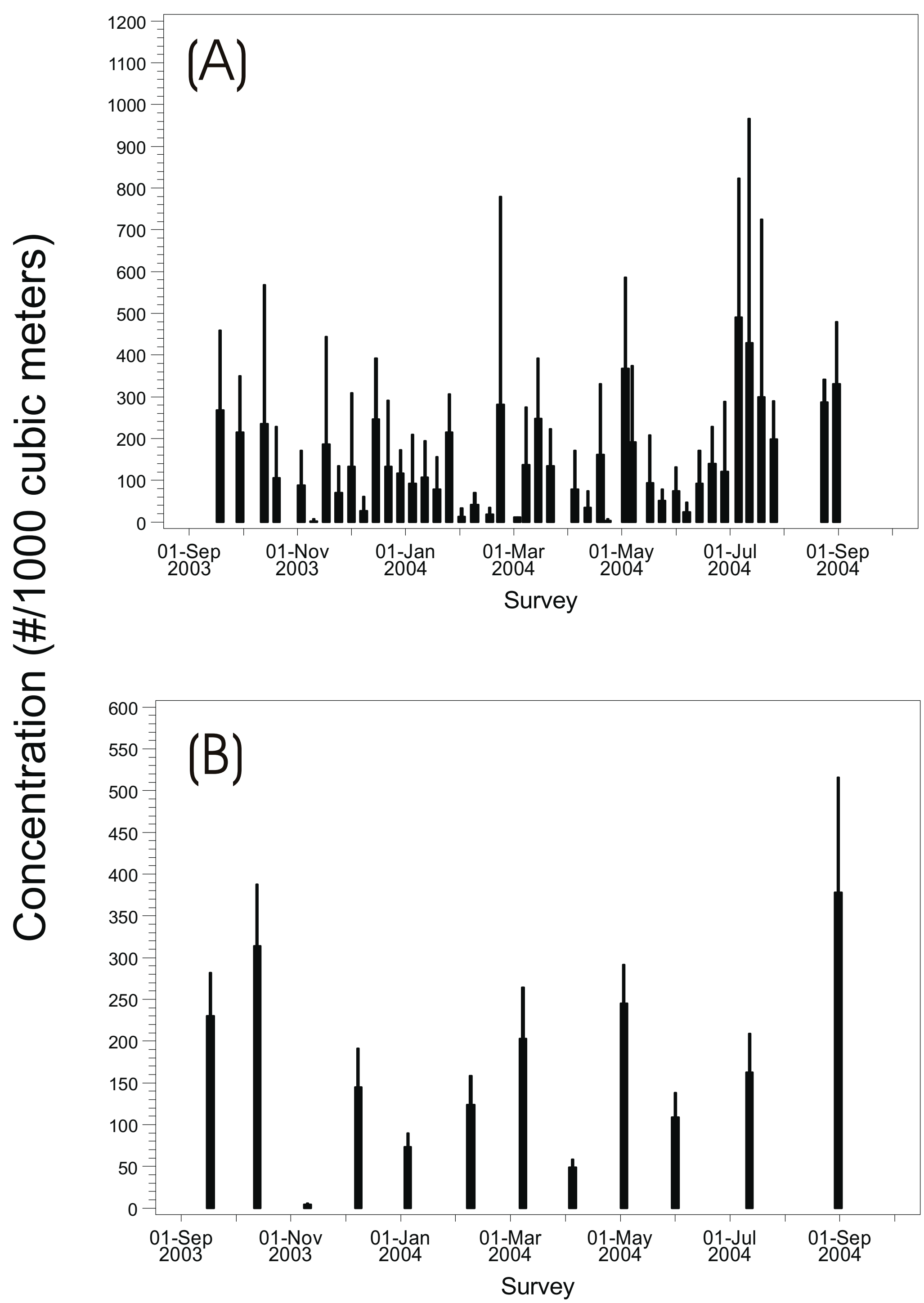

Figure 4-12. Survey mean concentration (#/1,000 m^3) of CIQ goby larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Note that the Y-axis range is different on the two graphs.

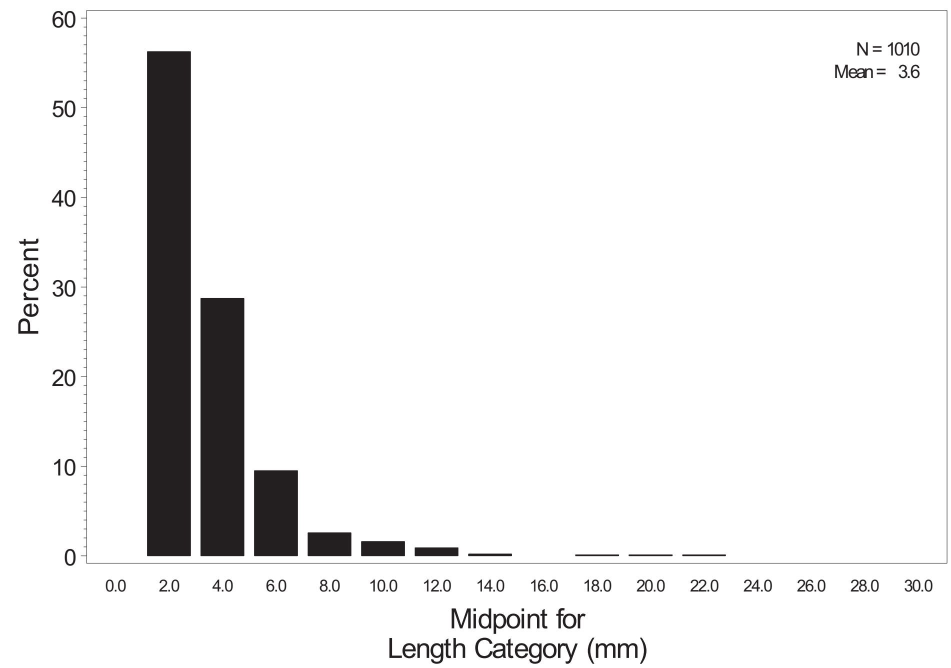

Figure 4-13. Length frequency distribution (mm) of all measured CIQ goby larvae collected at the HBGS entrainment station from September 2003 through August 2004.

Table 4-6. Total lifetime fecundity (TLF) estimates for three goby species based on a life history table in Brothers (1975).

Species	Age	N	% Mature	Fecundity	Spawns	No. Eggs	Eggs per Spawner*	TLF
Clevelandia ios	0	500	0					
	1	100	81	450	1.5	54,675	547	
	2	4	100	700	2.0	5,600	56	**603**
Ilypnus gilberti	0	500	0					
	1	80	10	260	0	0		
	2	51	71	480	1.5	26,071	511	
	3	14	99	720	3.0	29,938	587	
	4	2	100	900	3.0	5,400	106	**1,204**
Quietula y-cauda	0	500	0					
	1	74	23	410	0	0		
	2	50	87	620	1.5	40,455	809	
	3	26	99	840	2.5	54,054	1081	
	4	7	100	1,200	3.0	25,200	504	**2,394**
							Mean =	**1,400**

* A spawner is defined as a female at age of 1st spawning. This age varies among species.

Table 4-7. Results of *FH* modeling for CIQ goby complex larvae. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	42,709	37,070	10,243	178,079	167,836
Total Entrainment	33,927,750	1,969,133	38,632*	46,787*	8,155*

* Calculated using the standard error of the total entrainment estimate.

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for CIQ gobies was based on the difference between the estimated hatch length of 2.3 mm (0.09 in) and the length of the 95th (7.2 mm [0.28 in]) percentile divided by a growth rate of 0.16 mm/day (0.006 in/day). These values were used to estimate that CIQ goby larvae were vulnerable to entrainment for a period of approximately 31 days.

The *PE* estimates used to calculate *ETM* estimates for CIQ gobies ranged from 0.00010 to 0.00182 (**Table 4-8**). The average *PE* of 0.00069 is very close to the ratio of the projected HBDF daily flow to source water volumes of 0.00063 indicating that the volumetric ratio could be used to approximate the daily entrainment mortality. The values of f_i show that the highest numbers of CIQ goby larvae were collected during the August 2004 survey. CIQ goby larvae are transported out of embayments north and south of the HBGS and the distribution of the adults is limited to these areas. Therefore, only the P_M estimate based on alongshore current movement was calculated. The estimate of P_M for the 31-day period of exposure was 0.00212 (0.21%) (**Table 4-9**) over an area that was estimated to extend 76.7 km (47.7 mi) alongshore.

Table 4-8. *ETM* data for CIQ goby complex larvae. Average *PE* estimates were calculated from all surveys with $PE > 0$.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0.00074	0.00075	0.09340	0.06636
13-Oct-03	0.00041	0.00065	0.15955	0.10306
10-Nov-03	0.00034	0.00074	0.00218	0.00179
8-Dec-03	0.00010	0.00016	0.07560	0.07003
5-Jan-04	0.00079	0.00114	0.03845	0.02670
9-Feb-04	0.00021	0.00022	0.06557	0.05367
8-Mar-04	0.00041	0.00057	0.09670	0.08870
5-Apr-04	0.00125	0.00165	0.01810	0.01134
3-May-04	0.00114	0.00092	0.09705	0.05630
1-Jun-04	0.00047	0.00053	0.05763	0.04882
12-Jul-04	0.00182	0.00270	0.10986	0.08383
31-Aug-04	0.00055	0.00071	0.18591	0.18621
Average =	**0.00069**			

Table 4-9. Average P_S value and *ETM* estimate for alongshore current model for CIQ gobies. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1362 (76.7)	0.00212	0.28394	0.28605	0
Offshore Extrapolated	Not calculated				

4.3.4.2 Spotfin Croaker (*Roncador stearnsii*)

Spotfin croaker (*Roncador stearnsii*) is a croaker (Family Sciaenidae) common to the San Diegan fauna, which ranges from Mazatlan, Mexico to Point Conception, California, including the Gulf of California and occurs in depths ranging from the surf zone to 17 m (55.8 ft) (Miller and Lea 1972). Allen (1985) indicated spotfin croaker to be a common member of the open-coast, sandy-beach ichthyofauna, with seasonal occurrences in bays and harbors within the SCB.

4.3.4.2.1 Reproduction, Age, and Growth

Spotfin croaker is an oviparous broadcast spawner with pelagic eggs and larvae (Moser 1996). Gonosomatic index (GSI [gonad weight expressed as percent of gonad-free body weight]) peaked for both sexes in June (Miller et al. in press), while peak larval abundances were observed from June to September (Moser 1996). Although usually found in small groups (< 5 individuals), observations have been made of large aggregations (> 50 individuals; Feder et al. 1974). Initially thought to migrate offshore to spawn (Valle and Oliphant 2001), recent observations within the SCB indicate an inshore spawning ground, such as Seal Beach, California, based on seasonal fluctuations in catch per unit effort and GSI (Miller et al. in press). Valle and Oliphant (2001) estimated males to mature at two years old and 228.5 mm (8.9 in) SL, while females mature, on average, in their third year and 317.4 mm (12.5 in) SL.

At hatching, spotfin croaker yolk sac larvae are 2.1 mm (0.08 in) NL (notochord length), 5.5 mm (0.22 in) NL at flexion, and greater than 11 mm (0.43 in) SL at transformation (Moser 1996). Miller and Lea (1972) indicate the maximum length for spotfin croaker at 685.8 mm SL (25.9 in). Joseph (1962) observed the maximum age for spotfin croaker at 10 years based on scale aging. Spotfin croaker exhibit the greatest growth rate during the first and second year, with a mean increase of 100 mm (3.9 in) SL, quickly tapering off to less than 30 mm (1.2 in) SL per year after age five (Joseph 1962). No information on variation in growth by gender or mortality estimations is available for spotfin croaker.

4.3.4.2.2 Population Trends and Fishery

Spotfin croaker is the least frequently impinged croaker at coastal generating stations within the SCB (Herbinson et al. 2001). Since 1977, four generating stations within the SCB between San Onofre and Redondo Beach have reported spotfin croaker in impingement samples (Herbinson et al. 2001). Based on these impingement sample data, spotfin croaker populations in southern California have been low since 1983, although their abundance was less than all other croakers except white seabass (Herbinson et al. 2001). Nearshore gillnet sampling within the SCB has indicated a general rise in abundance, corresponding to a general rise in sea surface temperatures (Miller et al. in press).

Spotfin croaker has been reserved for recreational angling within California State waters since 1915, with a ban on the use of nets imposed in 1909 and a ban on commercial sale in 1915 (Valle and Oliphant 2001). Incidental catches were possible in the nearshore gillnet white seabass fishery, which was closed in 1992 by legislative action. Recreational angling, specifically surf-fishing, continues, as anglers enjoy greater success during periods of dense aggregation, such as spawning periods.

4.3.4.2.3 Sampling Results

Spotfin croaker larvae comprised 20.2% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period. It had the third highest mean concentration of all taxa collected in the entrainment samples for the study period with a mean concentration of 53.1 larvae per 1,000 m^3 (35,314.7 ft^3) (**Table 4-2**), but was relatively scarce in the combined source water samples with an overall mean concentration of only 1.6 larvae per 1,000 m^3 (**Table 4-4**). The higher abundance in the entrainment samples resulted from very high concentrations of larvae during a single survey in August 2004 when the mean concentration was measured at over 1,800 larvae per 1,000 m^3 (35,314.7 ft^3) (**Figure 4-14a**). The high, localized larval concentrations substantiate observations of nearshore spawning aggregations of spotfin croaker in summer. Spotfin croaker larvae in the source water samples were absent from September 2003 through April 2004 and were most abundant during August 2004 (**Figure 4-14b**).

The length frequency distribution of measured spotfin croaker larvae show an extremely limited size range dominated by recently hatched larvae based on the reported hatch length of 2.1 mm (0.08 in) (Moser 1996) (**Figure 4-15**). The mean, maximum, and minimum sizes for the measurements were 2.0, 2.5, and 1.3 mm (0.08, 0.1, and 0.5 in), respectively. A larval growth rate of 0.20 mm/day (0.008 in) for white croaker (Murdoch et al. 1989) was used with the difference in the lengths of the 10^{th} (1.7 mm [0.07 in]) and 95^{th} (2.4 mm [0.09 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 5 days. This was added to the estimated duration of the egg stage of 2 days from a related species white croaker (Watson 1982) for a total exposure of 7 days.

4.3.4.2.4 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on spotfin croaker larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of life history information necessary to parameterize the models.

Empirical Transport Model (*ETM*)

Only two *PE* estimates were calculated for spotfin croaker (**Table 4-10**). These estimates do not necessarily reflect the actual abundance of spotfin croaker because the highest abundances occurred during surveys when only the entrainment station was sampled (**Figure 4-14**). In addition to the large temporal variation in abundances, during one of the paired entrainment source water surveys the larvae were collected at the source water stations but not at the entrainment station indicating that the larvae may also be patchily distributed. As a result the larvae were not distributed throughout the sampling area limiting the extent to which the larval concentrations were extrapolated beyond the sampling area. As a result the two estimates of P_M were equal given the level of significant digits displayed and were both low (0.0004 [0.04%]) reflecting the short period of time (7 days) that the eggs and larvae were exposed to entrainment

(**Table 4-11**). The alongshore estimate of P_M was extrapolated over a shoreline distance of 33.9 km (11.4 mi), which was much less than the values for gobies or anchovy due to the shorter period of time the spotfin croaker larvae were exposed to entrainment.

Table 4-10. *ETM* data for spotfin croaker larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0	0	0	0
13-Oct-03	0	0	0	0
10-Nov-03	0	0	0	0
8-Dec-03	0	0	0	0
5-Jan-04	0	0	0	0
9-Feb-04	0	0	0	0
8-Mar-04	0	0	0	0
5-Apr-04	0	0	0	0
3-May-04	0.00108	0.00170	0.16060	0.19528
1-Jun-04	0	0	0	0
12-Jul-04	0	0	0.08960	0.15792
31-Aug-04	0.00014	0.00031	0.74979	0.26538
Average =	**0.00010**			

Table 4-11. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for spotfin croaker. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.3084 (33.9)	0.00040	0.36573	0.36613	0
Offshore Extrapolated	0.3041	0.00039	0.36572	0.36611	0

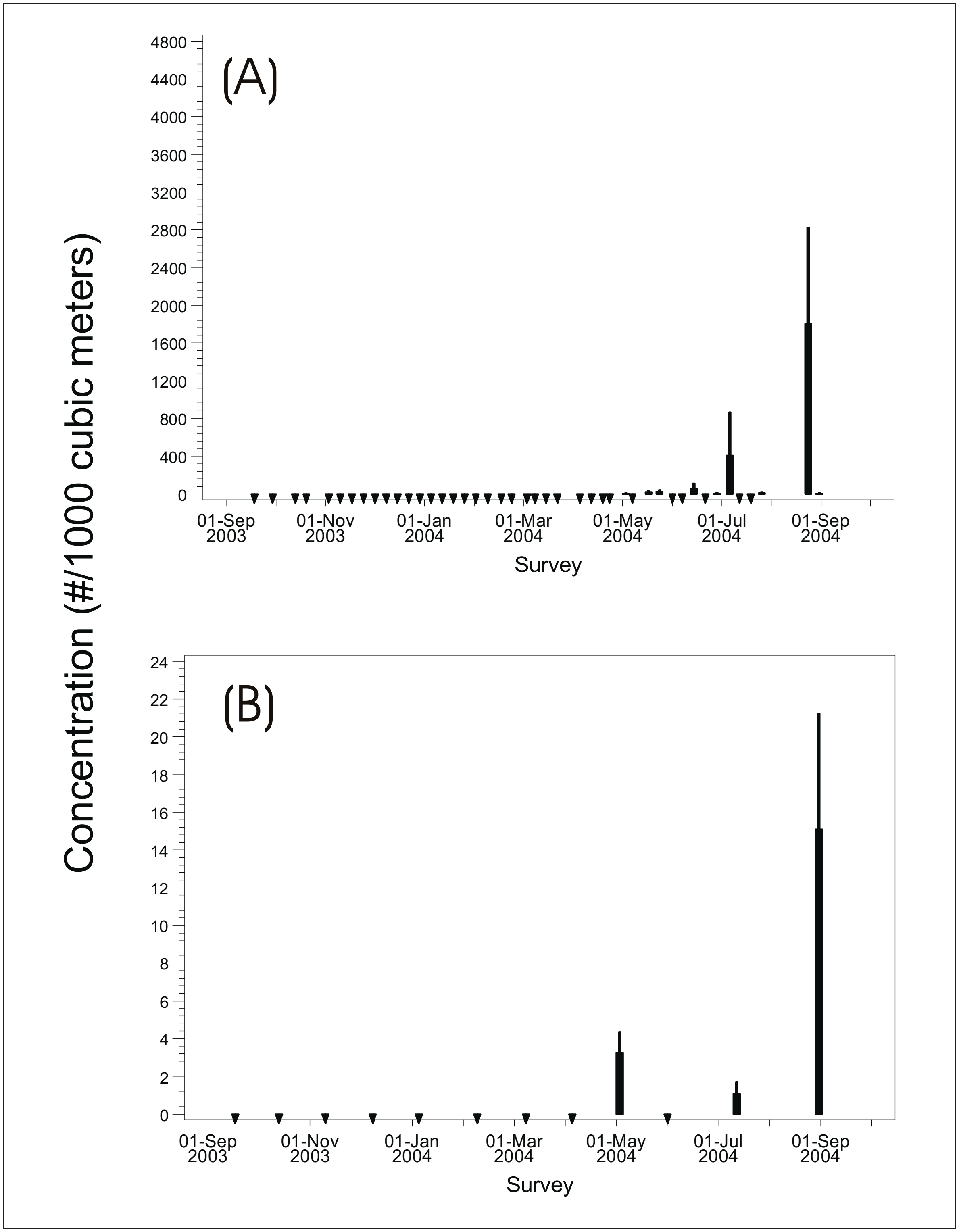

Figure 4-14. Survey mean concentration (#/1,000 m^3) of spotfin croaker larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no spotfin croaker larvae were collected.

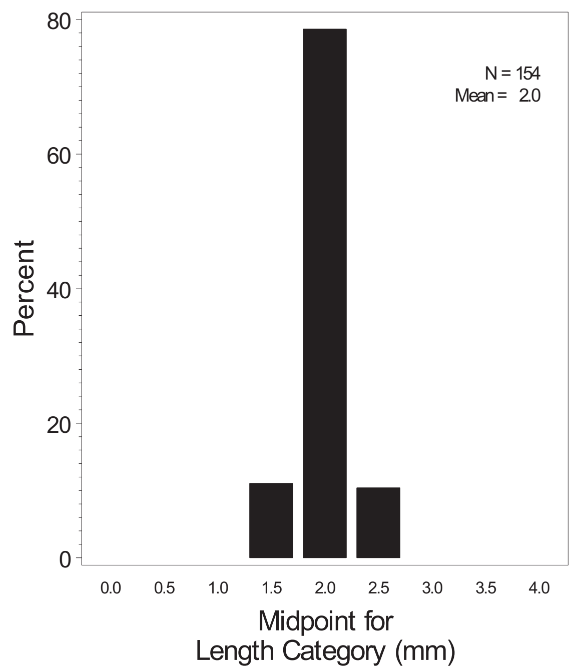

Figure 4-15. Length frequency distribution (mm) of all measured spotfin croaker larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.3 Northern Anchovy (*Engraulis mordax*)

Northern anchovy (*Engraulis mordax*) range from British Columbia to southern Baja California (Emmett et al. 1991). Juveniles are generally more common inshore and in estuaries. Eggs are found from the surface to 50 m (164 ft), and larvae are found from the surface to 75 m (246 ft) in epipelagic and nearshore waters (Garrison and Miller 1982). Northern anchovy larvae feed on dinoflagellates, rotifers, and copepods (MBC 1987), while juveniles and adults feed on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971, Frey 1971, Hart 1973, PFMC 1983). Northern anchovy feed largely during the night, though they were previously thought to feed mainly during the day (Allen and DeMartini 1983).

4.3.4.3.1 Reproduction, Age, and Growth

Northern anchovy spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978). Most spawning takes place within 100 km (62.1 mi) from shore (MBC 1987). On average, female anchovy off Los Angeles spawn every 7–10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980, MBC 1987). In 1979, it was determined that most spawning occurs at night (2100 to 0200 hr), with spawning complete by 0600 hr (Hunter and Macewicz 1980). Northern anchovy off southern and central California can reach sexual maturity by the end of their first year of life, with all individuals being mature by four years of age (Clark and Phillips 1952, Daugherty et al. 1955, Hart 1973). The maturation rate of younger individuals is dependent on water temperature (Bergen and Jacobsen 2001). Love (1996) reported that they release 2,700–16,000 eggs per batch, with an annual fecundity of up to 130,000 eggs per year in southern California. Parrish et al. (1986) and Butler et al. (1993) stated that the total annual fecundity for one-year old females was 20,000–30,000 eggs, while a five-year old could release up to 320,000 eggs per year.

The northern anchovy egg hatches in two to four days, has a larval phase lasting approximately 70 days, and undergoes transformation into a juvenile at about 35–40 mm (1.4-1.6 in) (Hart 1973, MBC 1987, Moser 1996). Larvae begin schooling at 11 to 12 mm (0.43-0.47 in) SL (Hunter and Coyne 1982). Collins (1969) presented age at length and weight at length regressions based on data from the southern California reduction fishery from which an average age 1 fish is estimated as 115 mm (4.5 in) weighing 14.9 g (0.5 oz). Northern anchovy reach 102 mm (4 in) in their first year, and 119 mm (4.7 in) in their second (Sakagawa and Kimura 1976). Growth in length is most rapid during the first four months, and growth in weight is most rapid during the first year (Hunter and Macewicz 1980, PFMC 1983). They mature at 78 to 140 mm (3.1 to 5.5 in) in length, in their first or second year (Frey 1971, Hunter and Macewicz 1980). Maximum size is about 230 mm (9 in) and 60 g (2.1 oz) (Fitch and Lavenberg 1971, Eschmeyer et al. 1983). Maximum age is about seven years (Hart 1973), though most live less than four years (Fitch and Lavenberg 1971).

4.3.4.3.2 Population Trends and Fishery

Northern anchovy are fished commercially for reduction (e.g., fish meal, oil, and paste) and live bait (Bergen and Jacobsen 2001). This species is the most important bait fish in southern California, and is also used in Oregon and Washington as bait for sturgeon (*Acipenser* spp.), salmonids (*Oncorhynchus* spp.), and other species (Emmett et al. 1991). Northern anchovy populations increased dramatically during the collapse of the Pacific sardine (*Sardinops sagax*) fishery, suggesting competition between these two species (Smith 1972).

Historically, estimates of the central subpopulation averaged about 325,700 metric tons (MT) (359,000 tons) from 1963 through 1972, then increased to over 1,542,200 MT (1.7 million tons) in 1974, then declined to 325,700 MT (359,000 tons) in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 391,900 MT (432,000 tons). The stock is thought to be stable, and the size of the anchovy resource is largely dependent on natural influences such as ocean temperature. Annual landings in the Los Angeles region since 2004 have varied from a high of nearly 2,000 MT (4.37 million lb) in 2005 to a low of 147 MT (0.32 million lb) in 2004 (**Table 4-12**), with an average of 2.60 million lb annually.

Table 4-12. Annual landings and revenue for northern anchovy in the Los Angeles region (PacFIN 2009).

Year	Landed Weight (MT)	Landed Weight (lb)	Revenue ($)
2004	147.0	324,087	$35,699
2005	1,980.0	4,365,130	$185,579
2006	866.0	1,909,139	$75,104
2007	927.5	2,044,713	$81,953
2008	1,967.7	4,338,137	$197,508
Average	**1,177.6**	**2,596,241**	**$115,169**

4.3.4.3.3 Sampling Results

Engraulidae larvae (over 95% of which were positively identified as northern anchovy) comprised 15.8% of the total estimated annual number of entrained larval fishes during the 2003–2004 study period (**Table 4-2**). It had the second highest mean concentration of all taxa collected in both the entrainment and source water samples (74.5 larvae per 1,000 m^3 and 81.4 larvae per 1,000 m^3, respectively) (**Tables 4-2 and 4-4**). The larvae that were identified only as Engraulidae, and not northern anchovy, were either very small or damaged specimens and could not be identified beyond the family level. The estimated mean entrainment concentration per survey was variable, ranging from zero to almost 400 larvae per 1,000 m^3 with high abundances in May, June and July (**Figure 4-16a**). Highest mean concentration of larvae sampled in the source water occurred in June 2004 (about 320 larvae per 1000 m^3), while concentrations were low in January and February 2004 (**Figure 4-16b**). The number and concentration of larval northern anchovy collected during each entrainment and source water survey are presented in MBC and Tenera (2005).

The length frequency distribution of measured northern anchovy larvae show a slightly bimodal distribution with approximately 10% being recently hatched larvae based on the reported hatch length of 2–3 mm (0.08-0.12 in) (Moser 1996) and a large number of larger larvae ranging from 6–40 mm (0.23-1.57 in) (**Figure 4-17**). The mean, maximum, and minimum sizes for the measurements were 11.8, 30.0, and 1.4 mm (0.45, 1.18, 0.06 in), respectively. A larval growth rate of 0.49 mm/day (0.02 in/day) was estimated from Methot and Kramer (1979). Statistical analysis of a random sample of 200 of the measured larvae was used to estimate a mean length of 11.6 mm (0.46 in), a hatch length of 2.9 mm (0.11 in) from the length of the 10th percentile of measurements, and the length at the 95th percentile of 20.47 mm (0.81 in). The difference in the lengths at hatching and the 95th percentile of the measurements was used with the larval growth rate to estimate that the larvae were exposed to entrainment for a period of 38 days. This was added to the duration of the egg stage of 2.9 days from Butler et al. (1993) for a total duration of exposure of 41 days.

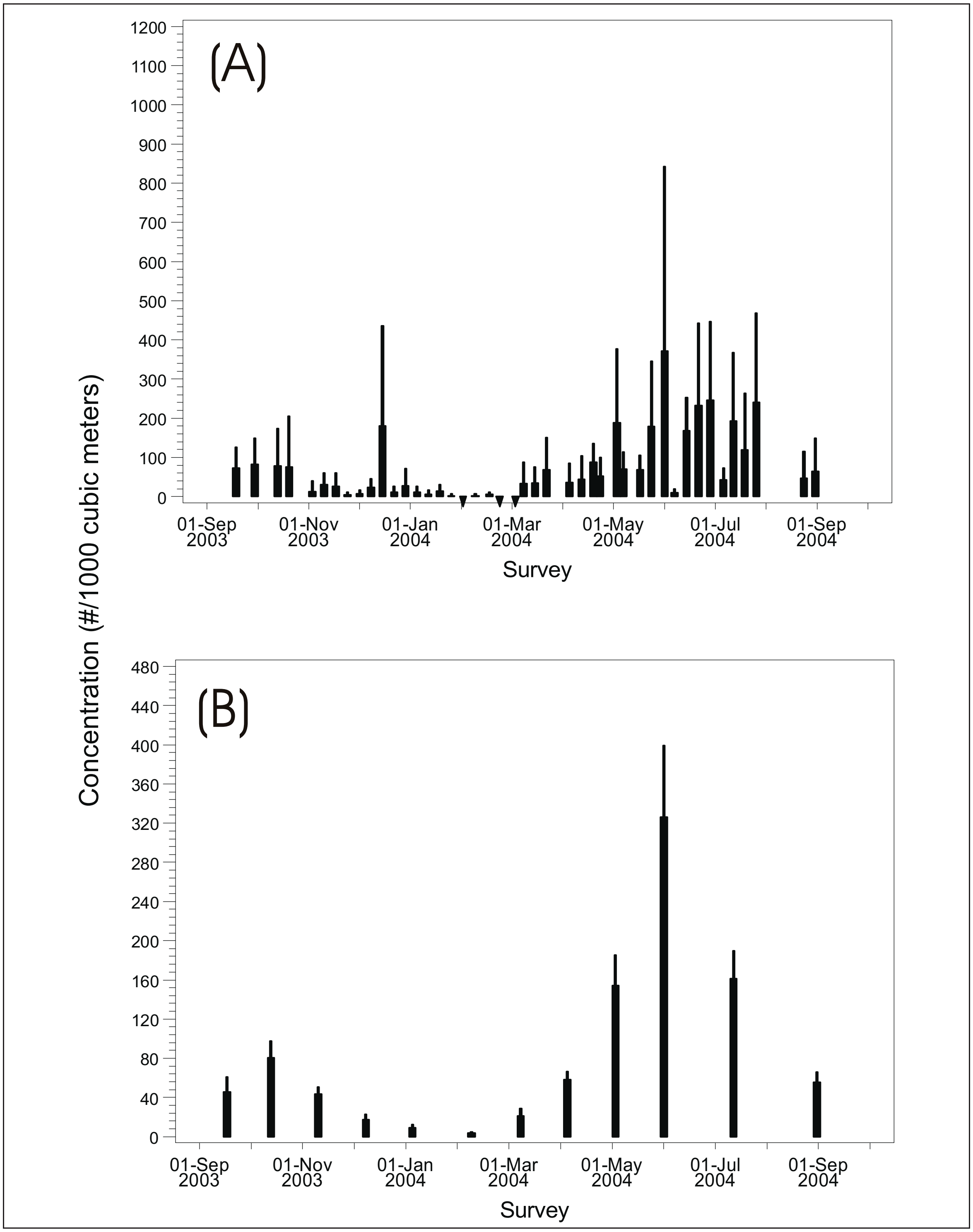

Figure 4-16. Survey mean concentration (#/1,000 m^3) of northern anchovy larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no northern anchovy larvae were collected.

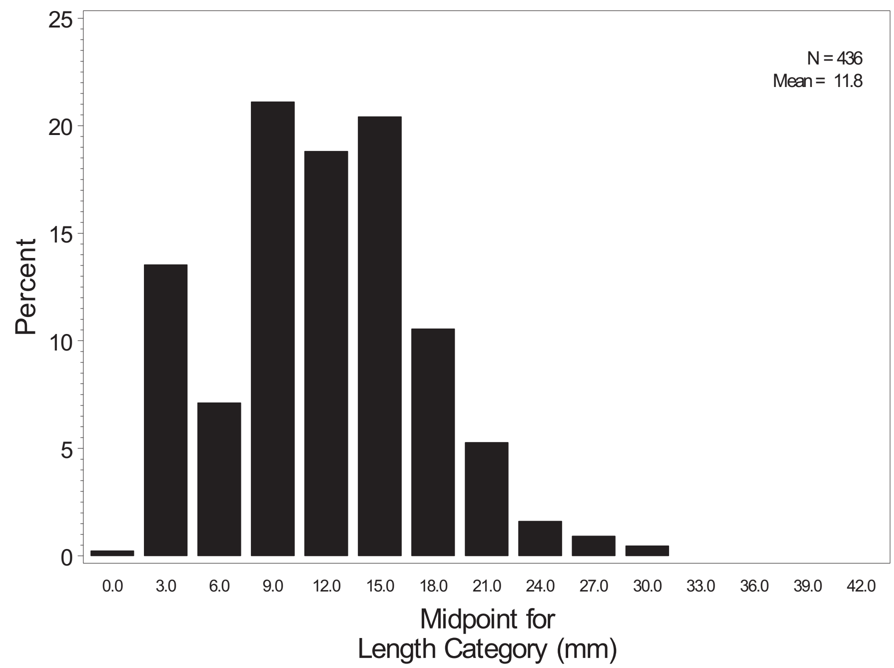

Figure 4-17. Length frequency distribution (mm) of all measured northern anchovy larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.3.4 Impact Assessment

The following sections present the results for demographic and empirical transport modeling of potential entrainment effects on northern anchovy larvae.

Fecundity Hindcasting (*FH*)

The entrainment estimates for northern anchovy larvae were used to estimate the number of breeding females at the age of maturity (age at which 50% of the females are mature) needed to produce the estimated number of larvae entrained. Butler et al. (1993) modeled annual fecundity and egg and larval survivorship for northern anchovy. Their "best" estimate can be derived by fitting the range of mortality estimates from field collections to the assumption of a stable and stationary population age structure. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage (**Table 4-13**). The average age of the eggs in the entrainment samples was assumed to be 1.29 days, the mean of an exponential distribution based on the *Z* for the egg stage from Butler et al. (1993). Survival to the average age was calculated as 0.51 using the egg survival over 2.9 days. Fish at the mean age of entrainment include yolk sac, early, and late stage larvae. Therefore, survival estimates for all three stages were combined to obtain a finite survival value of 0.007 up to the mean age at entrainment (17.7 days). The mean age at entrainment was calculated by dividing a larval growth rate of 0.41 mm/day (0.02 in/day) into the difference between the mean length of 11.6 mm (0.46 in) and the estimated hatch length of 2.9 mm (0.11 in).

Table 4-13. Stage-specific life history parameters for northern anchovy (*Engraulis mordax*) modified from Butler et al. (1993). Z = instantaneous daily mortality; S = finite survival rate.

Stage	Z_{best}	Stage duration (days)	Age (days)	S_{best}	CV_{best}
Egg	0.2310	2.9		0.512	0.142
Yolk-sac larva	0.3660	3.6	6.5	0.268	0.240
Early larva	0.2860	12	18.5	0.032	0.071
Late larva	0.0719	45	63.5	0.039	0.427
Early juvenile	0.0141	62	125.5	0.417	0.239
Late Juvenile	0.0044	80	205.5	0.703	0.033
Pre-recruit	0.0031	287	492.5	0.411	0.088

Clark and Phillips (1952) reported age at sexual maturity as 1–2 years. Similarly, Leet et al. (2001) reported that 47% to 100% of one-year olds may be mature in a given year while all are mature by two years. For modeling purposes we used a value of one year. For longevity, Hart (1973) reported a value of seven years, but Leet et al. (2001) stated that northern anchovy in the fished population rarely exceed four years of age. The survivorship values in **Table 4-14** were used to estimate an average annual fecundity of 163,090 eggs produced over a seven-year period using the data presented in Butler et al. (1993).

Table 4-14. Survivorship table for adult northern anchovy (*Engraulis mordax*) from Butler et al. (1993) showing spawners (L_x) surviving at the start of age interval and numbers of eggs spawned annually (M_x).

Age (year)	L_x	M_x	L_xM_x
1	1,000	22,500	22,500,000
2	468	93,500	43,800,000
3	216	195,000	42,000,000
4	102	280,000	28,600,000
5	48	328,000	15,700,000
6	22	328,000	7,210,000
7	10	328,000	3,280,000
		TLF*=	**163,090**

** Total lifetime fecundity (TLF) was calculated as the sum of L_xM_x divided by 1,000.*

The estimated number of adult female northern anchovy whose lifetime reproductive output was entrained through the HBDF feedwater system for the September 2003–August 2004 study period was 26,236 (**Table 4-15**). The *FH* estimate from the original HBGS study was only slightly greater at 26,745, which was due to the different method used in calculating the lifetime fecundity. The higher fecundity used in the earlier study will result in a lower *FH* estimate. In general the differences between the *FH* estimates from the two analyses should be roughly proportional to the flows used in the entrainment estimates. The results show that the variation in our estimate of entrainment had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the model.

Table 4-15. Results of *FH* modeling for northern anchovy larvae. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	26,236	22,818	6,274	109,710	103,436
Total Entrainment	16,293,995	1,305,874	22,777*	29,695*	6,918*

* Calculated using the standard error of the total entrainment estimate.

Adult Equivalent Loss (*AEL*)

The larval entrainment estimate for northern anchovy was used to estimate the number of equivalent adults lost to entrainment. The parameters required for formulation of *AEL* estimates include larval survival from entrainment to settlement and survival from settlement to the average age of reproduction for a mature female. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage. The larval stage survival was adjusted to the mean age at entrainment (17.7 days) and used to calculate a finite survival through age 63.5 days of 0.046 using the daily survival rates for late stage larvae. The other finite survival rates from Butler et al. (1993) were used to estimate the number of adults of age one year, the age of reproductive females used in calculating the average lifetime fecundity estimate used in the *FH* model.

The estimated number of adult northern anchovy equivalent to the number of larvae entrained through the HBGS circulating water system using the flows for the HBDF was 365,837 (**Table 4-16**). The *AEL* estimate from the original HBGS study was approximately the same at 304,125, which was due to the different adult age used in the extrapolation. In the previous study instead of age one, the *AEL* was extrapolated to age 2.75 years, resulting in a lower estimate relative to the original entrainment estimate. In general the differences between the *AEL* estimates from the two analyses should be roughly proportional to the flows used in the entrainment estimates.

The results show that the variation in our estimate of entrainment had much less of an effect on the variation of the *AEL* estimate than the life history parameters used in the model. If all of our life history parameters and assumptions regarding lifetime fecundity were accurate the *AEL* estimate should approximately equal twice the *FH* estimate. The results show that the *AEL* estimate greatly exceeds the 2*FH* estimate (52,472). The large range of *AEL* indicates the high level of uncertainty associated with the life history parameters that are available and used in the model.

Table 4-16. Results of *AEL* modeling for northern anchovy larvae entrained during the September 2003–August 2004 sampling period. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	AEL Lower Estimate	AEL Upper Estimate	AEL Range
AEL	365,837	424,181	54,317	2,463,985	2,409,668
Total Entrainment	16,293,995	1,305,874	317,606*	414,068*	96,462*

* Calculated using the standard error of the total entrainment estimate.

Empirical Transport Model (*ETM*)

The *PE* estimates used to calculate *ETM* for northern anchovy for the September 2003–August 2004 study period ranged from 0.00036 to 0.00114 (**Table 4-17**). The average *PE* of 0.00075 is very close to the ratio of the projected HBDF daily flow to source water volumes of 0.00063 indicating that the volumetric ratio could be used to approximate the daily entrainment mortality. As shown in the values of f_i the largest abundance of anchovy larvae was collected during the June 2004 survey. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 38-day period of exposure calculated using offshore extrapolated densities (0.0012, 0.12%) is less than the estimate calculated using alongshore current displacement (0.0024, 0.24%) because of the larger overall volume of the source area calculated due to the offshore extrapolation (**Table 4-18**). The P_S estimates indicate that the ratios of the sampled source water to the total population were 3 and 11% for offshore and alongshore, respectively. The alongshore estimate of P_M was extrapolated over a shoreline distance of 94.8 km (58.9 mi).

Table 4-17. *ETM* data for northern anchovy larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0.00110	0.00140	0.03292	0.03400
13-Oct-03	0.00058	0.00078	0.07234	0.04127
10-Nov-03	0.00044	0.00048	0.03914	0.02047
8-Dec-03	0.00092	0.00118	0.01453	0.01320
5-Jan-04	0.00084	0.00153	0.00852	0.01003
9-Feb-04	0.00045	0.00103	0.00352	0.00391
8-Mar-04	0.00114	0.00218	0.01642	0.01736
5-Apr-04	0.00036	0.00050	0.05654	0.02337
3-May-04	0.00091	0.00104	0.12008	0.06606
1-Jun-04	0.00075	0.00104	0.34788	0.14091
12-Jul-04	0.00074	0.00075	0.23432	0.09584
31-Aug-04	0.00072	0.00100	0.05380	0.02862
Average =	**0.00075**			

Table 4-18. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for northern anchovy. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1101 (94.8)	0.00236	0.20204	0.20440	0
Offshore Extrapolated	0.0267	0.00118	0.19929	0.20047	0

4.3.4.4 Queenfish (*Seriphus politus*)

Queenfish (*Seriphus politus*) range from west of Uncle Sam Bank, Baja California, north to Yaquina Bay, Oregon (Miller and Lea 1972). Queenfish are common in southern California, but rare north of Monterey. They are one of eight species of croaker or 'drums' (Family Sciaenidae) found off California. The reported depth range of queenfish is from the surface to depths of about 37 m (120 ft) (Miller and Lea 1972); however, in southern California, Allen (1982) found queenfish over soft bottoms between 10 and 70 m (32.8 and 229.7 ft), with highest abundance occurring at 10 m (32.8 ft). During the day, queenfish hover in dense, somewhat inactive schools close to shore, but disperse to feed in the midwater after sunset (Hobson and Chess 1976).

4.3.4.4.1 Reproduction, Age, and Growth

Queenfish is a summer spawner. Goldberg (1976) found queenfish enter spawning condition in April and spawn into August, while DeMartini and Fountain (1981) recorded spawning in queenfish between March and August. Spawning is asynchronous among females, but there are monthly peaks in intensity during the waxing (first quarter) of the moon (DeMartini and Fountain 1981). They also stated that mature queenfish spawn every 7.4 days on average, regardless of size. Duration of the spawning season is a function of female body size, ranging from three months (April–June) in recruit spawners to six months (March–August) in repeat spawners (>13.5 cm [5.3 in] SL). Based on the spawning frequency and number of months of spawning, these two groups of spawners can produce about 12 and 24 batches of eggs during their respective spawning seasons (DeMartini and Fountain 1981).

Goldberg (1976) found no sexually mature females less than 14.8 cm (5.8 in) SL in Santa Monica Bay. This differs from the findings of DeMartini and Fountain (1981) off San Onofre. They found females sexually mature at 10.0–10.5 cm (3.9-4.1 in) SL at slightly greater than Age-1. Batch fecundities in queenfish off San Onofre ranged from 5,000 eggs in a 10.5-cm (4.1 in) female to about 90,000 eggs in a 25-cm (9.8 in) fish. The average-sized female in that study (14 cm [5.5 in], 42 g [1.5 oz]) had a potential batch fecundity of 12,000–13,000 eggs. Murdoch (1989a) estimated the average batch fecundity to be 12,700 for queenfish collected over a five-year period. Based on a female spawning frequency of 7.4 days, a 10.5-cm (4.1 in) female that spawns for three months (April–June) can produce about 60,000 eggs/year, while a 25-cm (9.8 in) female that spawns for six months (March through August) can produce nearly 2.3 million eggs/year (DeMartini and Fountain 1981).

Male and female queenfish reach 50% maturity by age 1, or approximately 10 cm SL (4 in) (Miller et al. 2009), during their first spring or second summer (DeMartini and Fountain 1981). Immature individuals grow at a rate of about 2.5 mm/day (0.1 in/day), while early adults grow about 1.8 mm/day (0.07 in/day) (Murdoch et al. 1989b). Maximum reported size is 30.5 cm total length (TL) (12 in) (Miller and Lea 1972).

4.3.4.4.2 Population Trends and Fishery

Queenfish was the most abundant croaker impinged at five generating stations (including the HBGS) from 1977 through 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Annual abundance fluctuated from year to year, with notable declines during the strong El Niño events of 1982–83, 1986–87, and 1997–98. However, abundance remained relatively high throughout the 21-year study period. Abundances based on research trawl catches in the vicinity of HBGS peaked in 1983 and 1993, followed by substantial declines lasting at least 10 years after each peak (Miller et al. 2009). There were no individuals taken in 2004 or 2007, the two most recent surveys analyzed. The cause of the cyclical nature of the catches was not known, but interannual changes in sea surface temperature were not correlated with catch per unit effort (CPUE) (Miller et al. 2009). Queenfish populations have declined in the SCB, and these declines are thought to be related to decreasing zooplankton biomass throughout the western North Pacific concurrent with shifts in the climatic regime (Miller et al. 2009).

There were no reported commercial landings of queenfish in the PacFIN records from 2000–2008 (PacFIN 2009), although it is possible that they have been included under the 'unspecified croaker' category. Annual recreational landings in southern California have averaged 265,400 fish per year since 2004, with notable declines in the past several years (RecFIN 2009; **Table 4-19**).

Table 4-19 Annual recreational fishing catch estimates for queenfish in the southern California region (RecFIN 2009).

Year	Estimated Catch	Estimated Weight (lb)
2004	532,000	15,400
2005	258,000	33,000
2006	231,000	44,100
2007	162,000	28,700
2008	144,000	17,600
Average	**265,400**	**27,760**

4.3.4.4.3 Sampling Results

Queenfish larvae comprised 5.2% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period. Queenfish larvae were the fifth most abundant taxon based on mean concentration collected from the entrainment station (18.2 larvae per 1,000 m^3) and the third most abundant from the source water stations (45.9 larvae per 1,000 m^3) during the sampling period (**Tables 4-2** and **4-4**). This species was found in the entrainment samples collected from May through August, with a peak concentration of over 300 larvae per 1,000 m^3 (35,314.7 ft^3) during August 2004 (**Figure 4-18a**). Queenfish larvae were found at the source water stations during the same period of the year with a few individuals also being seen in October 2003 and January 2004 (**Figure 4-18b**).

The length frequency distribution of the measured queenfish at the entrainment station is shown in **Figure 4-19**. The mean, maximum and minimum measurements were 4.9, 20.4 and 1.5 mm (0.2, 0.8, and 0.06 in), respectively. The majority of the larvae collected were not newly hatched, as Moser (1996) reported a hatch length of about 1.6 mm (0.06 in) for queenfish. Only about 15% of the queenfish larvae were between 1 and 3 mm (0.04 and 0.12 in) total length.

4.3.4.4.4 Impact Assessment

The following sections present the results for fecundity hindcasting and empirical transport modeling of entrainment effects on queenfish larvae.

Fecundity Hindcasting (*FH*)

The entrainment estimate for queenfish larvae was used to estimate the number of breeding females needed to produce the estimated number of larvae entrained. (**Table 4-20**). Estimates of egg survival from white croaker, a related species, and estimates of queenfish larval survival (Miller et al. in press) were used to estimate a finite survival value up to the mean age at entrainment. Information on fecundity from DeMartini and Fountain (1981) and age, growth, and reproduction from Miller et al. (2009) were used to estimate a total lifetime fecundity of 1,430,000 eggs.

The estimated number of adult female queenfish whose lifetime reproductive output would be entrained through the HBGS intake due to operation of the HBDF was estimated at seven fish (**Table 4-20**). The results show that the variation in our estimate of entrainment had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the model.

Table 4-20. Results of *FH* modeling for queenfish larvae. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	7	6	2	30	28
Total Entrainment	5,339,449	724,170	6*	9*	3*

* Calculated using the standard error of the total entrainment estimate.

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for queenfish was based on the difference between the lengths of the 10^{th} (1.9 mm [0.07 in]) and 95^{th} (7.1 mm [0.3 in]) percentiles and a daily larval growth rate of 0.20 mm/day (0.008 in/day) from Murdoch et al.

(1989). These values were used to estimate that queenfish larvae were vulnerable to entrainment for a period of 28 days. This was added to the estimated duration of the egg stage of 2 days from a related species white croaker (Watson 1982) to calculate the total exposure at 30 days.

Only two *PE* estimates could be calculated for queenfish for the September 2003–August 2004 period (**Table 4-21**). This was due to queenfish larvae only being present in two of the paired entrainment and source water surveys (**Figure 4-18**). Although queenfish larvae were collected at only the source water stations in four additional surveys, over 99% of the larvae in the source samples were collected during the two surveys when they were also collected at the entrainment station. These two *PE* values for these surveys were similar in value, 0.00049 and 0.00044. The P_S estimates (**Table 4-22**) were 0.1141 (11.4%) for the alongshore current and 0.0164 (1.6%) for offshore-extrapolated current movement for the 30-day exposure period. The two estimates of mortality, P_M, were 0.00075 (0.075%) using the alongshore current and 0.00053 (0.053%) using the offshore extrapolation. The alongshore estimate of P_M was extrapolated over a shoreline distance of 91.5 km (56.9 mi).

Table 4-21. *ETM* data for queenfish larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0	0	0	0
13-Oct-03	0	0	0.00309	0.00647
10-Nov-03	0	0	0	0
8-Dec-03	0	0	0	0
5-Jan-04	0	0	0.00249	0.00507
9-Feb-04	0	0	0	0
8-Mar-04	0	0	0	0
5-Apr-04	0	0	0	0
3-May-04	0	0	0.00122	0.00245
1-Jun-04	0	0	0.00305	0.00382
12-Jul-04	0.00049	0.00073	0.23174	0.19339
31-Aug-04	0.00044	0.00056	0.75841	0.19441
Average =	**0.00008**			

Table 4-22. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for queenfish. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1141 (91.5)	0.00075	0.27548	0.27622	0
Offshore Extrapolated	0.0164	0.00053	0.27517	0.27570	0

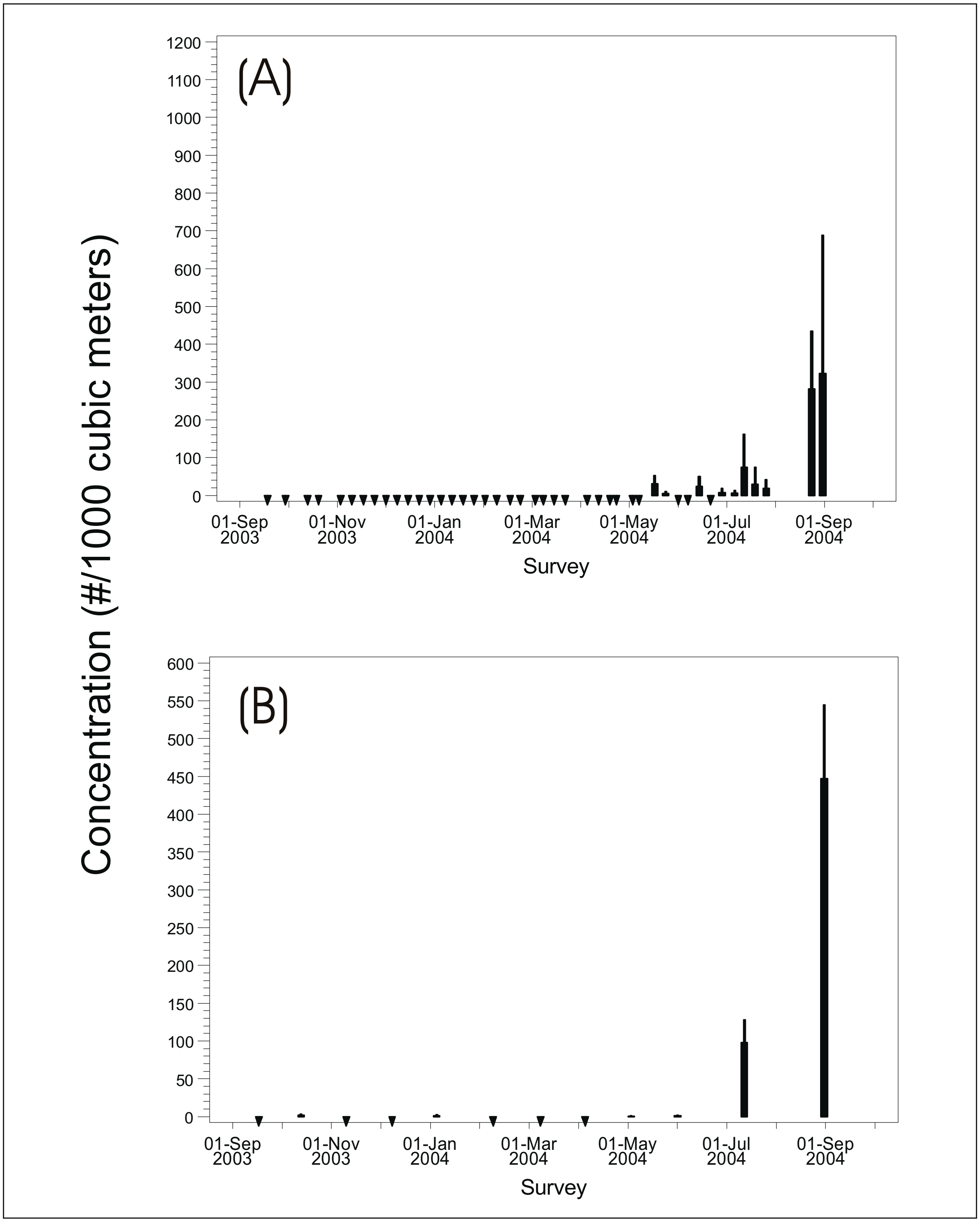

Figure 4-18. Survey mean concentration (#/1,000 m^3) of queenfish larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no queenfish larvae were collected.

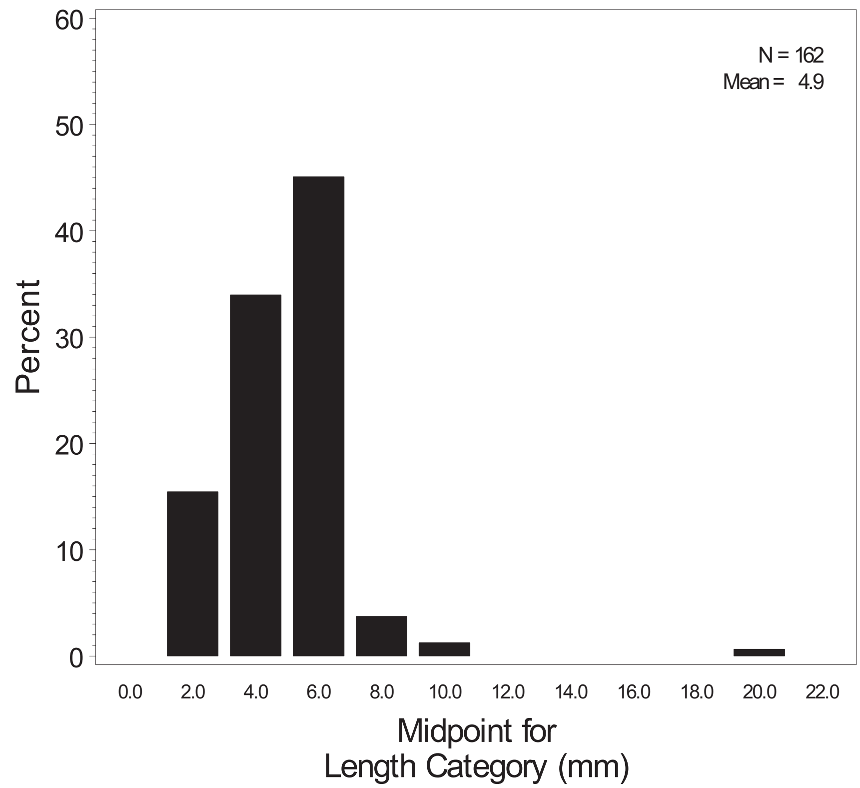

Figure 4-19. Length frequency distribution (mm) of all measured queenfish larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.5 White Croaker (*Genyonemus lineatus*)

White croaker (*Genyonemus lineatus*) range from Magdalena Bay, Baja California, north to Vancouver Island, British Columbia (Miller and Lea 1972). They are one of eight species of croakers (Family Sciaenidae) found off California. The reported depth range of white croaker is from the surface to depths of 183 m (600 ft) (Miller and Lea 1972, Love et al. 1984); however, in southern California, Allen (1982) found white croaker over soft bottoms between 10 and 130 m (32.8 and 426.5 ft), and it was most frequently collected at 10 m (23.8 ft).

4.3.4.5.1 Reproduction, Age, and Growth

White croaker is an oviparous broadcast spawner. They mature between about 130 and 190 mm (5.1 and 7.5 in) TL, somewhere between the first and fourth years. About one-half of males mature by 140 mm (5.5 in) TL, and one-half of females by 150 mm (5.9 in) TL, and all fishes are mature by 190 mm (7.5 in) TL in their third to fourth year (Love et al. 1984). Off Long Beach, California, white croaker spawn primarily from November through August, with peak spawning from January through March (Love et al. 1984). However, some spawning can occur year-round.

Batch fecundities ranged from about 800 eggs in a 155 mm (6.1 in) female to about 37,200 eggs in a 260 mm (10.5 in) female, with spawning taking place as often as every five days (Love et al. 1984). In their first and second years, females spawn for three months for a total of about 18 times per season. Older individuals spawn for about four months and about 24 times per season (Love et al. 1984). Some older fish may spawn for seven months. The nearshore waters from Redondo Beach (Santa Monica Bay, California) to Laguna Beach, California, are considered an important spawning center for this species (Love et al. 1984).

Newly hatched white croaker larvae are 1–2 mm SL (0.04–0.08 in) and not well developed (Watson 1982). Larvae are principally located within 4 km (2.5 mi) from shore, and as they develop tend to move shoreward and into the epibenthos (Schlotterbeck and Connally 1982). Murdoch et al. (1989c) estimated a daily larval growth rate of 0.20 mm/day (0.008 in/day). Maximum reported size is 414 mm (16.3 in) (Miller and Lea 1972), with a life span of 12–15 years (Frey 1971, Love et al. 1984). White croaker grows at a fairly constant rate throughout their lives, though females outgrow males from age 1.

4.3.4.5.2 Population Trends and Fishery

White croaker was the second most abundant croaker impinged at five generating stations (including the HBGS) from 1977 through 1998 (Herbinson et al. 2001). Annual abundance declined during that period, with marked decreases during the strong El Niño events of 1982–83, 1986–87, and 1997–98.

White croaker is an important constituent of the commercial and sport fisheries of California. Before 1980, statewide white croaker landings averaged 310,710.7 kg (685,000 lb) annually, exceeding 453,592.4 kg (1,000,000 lb) in several years (Moore and Wild 2001). Highest landings in 1952 corresponded with the collapse of the Pacific sardine fishery. Since 1991, landings averaged 209,106.1 kg (461,000 lb) and steadily declined to an all-time low of 64,636.9 kg (142,500 lb) in 1998. Prior to 1980, most of the croaker catch was in southern California. However, since 1980, the majority of the commercial catch has occurred in central California (Moore and Wild 2001).

Most of the recreational catch still occurs in southern California from piers, breakwaters, and private boats. Annual recreational landings in southern California from all sources have averaged approximately 140,400 fish per year since 2004, with the highest catches of nearly 300,000 fish recorded in 2007 (RecFIN 2009; **Table 4-23**). Commercial landings over the same period averaged 8.3 MT per year with an average annual ex-vessel value reported to be $9,873 (**Table 4-23**).

Table 4-23. White croaker recreational fishing catch in southern California, and commercial fishing landings and ex-vessel value in Los Angeles County, 2004-2008. Data from RecFIN (2009) and PacFIN (2009).

Year	Estimated Recreational Catch (MT)	Estimated Recreational Catch (No.)	Commercial Landings (MT)	Ex-vessel Revenue ($)	Revenue per pound ($)
2004	22	120,000	8.9	$14,653	$0.75
2005	24	155,000	11.2	$17,531	$0.71
2006	10	71,000	6.8	$11,079	$0.74
2007	42	297,000	5.4	$4,000	$0.33
2008	8	59,000	9.2	$2,104	$0.10
Average	**21.2**	**140,400**	**8.3**	**$9,873**	**$0.54**

4.3.4.5.3 Sampling Results

White croaker larvae comprised 5.1% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period (**Table 4-2**). It had the fourth highest mean concentration of all taxa collected in both the entrainment and source water samples (28.1 larvae per 1,000 m^3 and 39.5 larvae per 1,000 m^3, respectively) (**Tables 4-2 and 4-4**). The estimated mean concentration per survey was variable, ranging from zero to about 135 white croaker larvae per 1,000 m^3 (**Figure 4-20a**). Peaks in abundance occurred during April and May 2004. The May peak in abundance coincided with the peak abundance at the source water stations (**Figure 4-20b**), but a second peak at the source water stations in August 2004 was not reflected in the data from the entrainment station.

The length frequency distribution of measured white croaker larvae included a wide size range (**Figure 4-21**) which was dominated by recently hatched larvae, based on a reported hatch length of 1–2 mm (0.04–0.08 in) (Watson 1982). The mean, maximum, and minimum sizes for the measurements were 3.5, 9.1, and 1.4 mm (0.14, 0.42, and 0.06 in), respectively. A larval growth rate of 0.20 mm/day (0.008 in/day) for white croaker (Murdoch et al. 1989c) was used with the difference in the lengths of the 10^{th} (1.8 mm [0.07 in]) and 95^{th} (7.0 mm [0.3 in]) percentiles from a random sample of 200 of the measurements of the larvae collected at the intake to estimate that the larvae were exposed to entrainment for a period of 27 days. The estimated duration of the egg stage of 2 days from Watson (1982) was added to the larval duration for a total duration of approximately 29 days.

4.3.4.5.4 Impact Assessment

The following sections present the results for fecundity hindcasting and empirical transport modeling of potential entrainment effects on white croaker larvae. No age-specific estimates of survival for later stages of development were available from the literature for white croaker; therefore no estimates of *AEL* could be calculated.

Fecundity Hindcasting (FH)

The entrainment estimate for white croaker larvae was used to estimate the number of breeding females needed to produce the estimated number of larvae entrained (**Table 4-24**). White croaker estimates of egg survival and estimates of larval survival (Miller et al. in press) were used to estimate a finite survival value up to the mean age at entrainment. Information on fecundity from Love et al. (1984) and Love (1996) and age, growth, and reproduction from Miller et al. (2009) were used to estimate a total lifetime fecundity of 525,000 eggs. The estimated number of female white croaker at the age of first maturity whose lifetime reproductive output would be entrained under a 152 mgd flow rate was calculated to be 18 fish (**Table 4-24**). The results of the sensitivity analysis show that the greatest uncertainty associated with the estimate is related to the life history parameters in the model and not the entrainment estimate.

Table 4-24. Results of *FH* modeling for white croaker larvae. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	18	16	4	75	71
Total Entrainment	5,284,106	447,107	16*	21*	5*

* Calculated using the standard error of the total entrainment estimate.

Empirical Transport Model (ETM)

The *PE* estimates used to calculate *ETM* for white croaker for the September 2003–August 2004 period varied considerably among surveys and ranged from 0 to 0.00102 (**Table 4-25**). The largest *PE* estimate was calculated for the September 2003 survey, but the largest proportions of the source population (f_i) were present during the May and August 2004 surveys. The average *PE* of 0.00041 is close to the ratio of the projected HBDF daily flow to source water volumes of 0.00063 indicating that the volumetric ratio could be used to approximate the daily entrainment mortality. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 29-day period of exposure calculated using offshore extrapolated densities (0.00044, 0.044%) is less than the estimate calculated using alongshore current displacement (0.00100, 0.100%) because the effects of entrainment are spread over a much larger source population (**Table 4-26**). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 13.9% and 5.1%, respectively. The alongshore estimate of P_M was extrapolated over a shoreline distance of 75.4 km (46.9 mi).

Table 4-25. *ETM* data for white croaker larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0.00102	0.00183	0.01722	0.01426
13-Oct-03	0.00043	0.00072	0.02892	0.02256
10-Nov-03	0.00008	0.00010	0.07104	0.03526
8-Dec-03	0.00026	0.00049	0.11844	0.07330
5-Jan-04	0.00054	0.00094	0.05064	0.02916
9-Feb-04	0.00075	0.00100	0.02628	0.01944
8-Mar-04	0.00068	0.00110	0.02362	0.01357
5-Apr-04	0.00015	0.00031	0.02002	0.01315
3-May-04	0.00059	0.00051	0.28073	0.10793
1-Jun-04	0.00040	0.00065	0.06375	0.06356
12-Jul-04	0	0	0.02898	0.02505
31-Aug-04	0.00001	0.00002	0.27036	0.15099
Average =	**0.00041**			

Table 4-26. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for white croaker. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1385 (75.4)	0.00100	0.22128	0.22228	0
Offshore Extrapolated	0.0509	0.00044	0.22010	0.22054	0

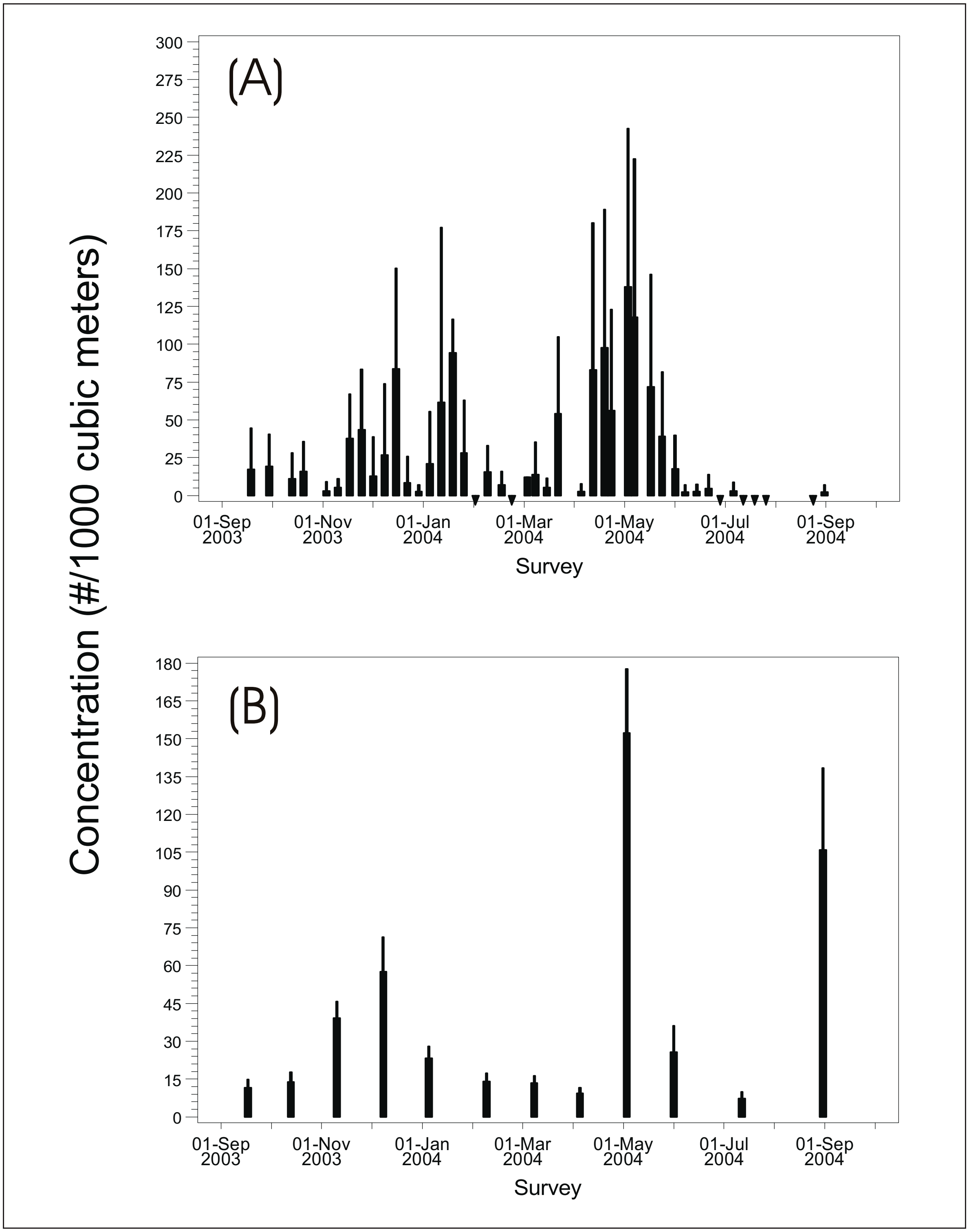

Figure 4-20. Survey mean concentration (#/1,000 m^3) of white croaker larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no white croaker larvae were collected.

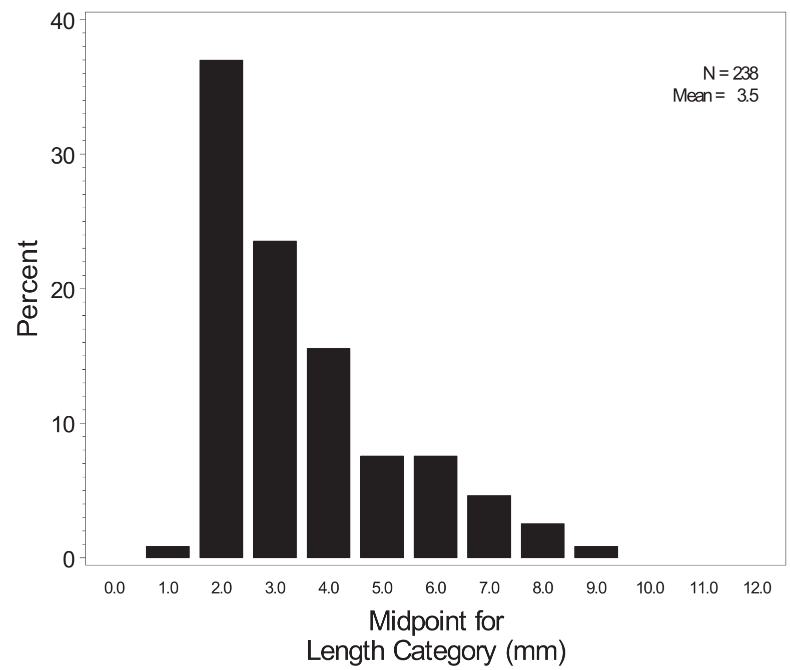

Figure 4-21. Length frequency distribution (mm) of white croaker larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.6 Salema (*Xenistius californiensis*)

Salema (*Xenistius californiensis*) is one of two grunts (Family Haemulidae) common to southern California, and ranges from Peru to Monterey Bay, California, including the Gulf of California in depths ranging from 1–12 m (3.3–39.4 ft) (Miller and Lea 1972). Sargo (*Anisotremus davidsonii*) is the other representative of the grunt family common to southern California (Miller and Lea 1972). Salema occur mainly in shallow rocky reefs and kelp bed habitats throughout the SCB in areas also frequented by black croaker (*Cheilotrema saturnum*) (Quast 1968, Allen 1985). Salema are nocturnal and can form large schools around piers and on algae-covered rocky reefs (Robertson and Allen 2002).

4.3.4.6.1 Reproduction, Age, and Growth

Salema are oviparous, producing planktonic eggs and larvae during the summer months (Moser 1996). Preliminary observations of salema gonads indicate reproductive activity from June to September, with gonads reduced to being nearly unidentifiable during April (E. Miller, MBC, personal observation). Gonosomatic index analyses indicate peak spawning in August with dramatic declines by October in both sexes (Miller, unpubl. data). Gillnet sampling resulted in significantly higher percentages of females during peak spawning periods (Miller, unpubl. data).

No information on the age and growth of salema is currently available. The recorded hatch length of the larvae is less than 2.2 mm (0.09 in) (Moser 1996). Miller and Lea (1972) reported that salema have a maximum length of 25.4 cm (10 in).

4.3.4.6.2 Population Trends and Fishery

Quast (1968) noted salema densities to be 2.57 kg/acre in kelp beds near Corona Del Mar, California. Salema have been observed in impingement samples at most coastal generating stations throughout the SCB, especially those in the vicinity of kelp beds. Impingement rates for salema at ESGS since 1978 indicate an increase in salema populations (MBC and Herbinson, unpublished data). Currently, no commercial or recreational fishery targets salema, probably due to their nocturnal activity and small size. Incidental catches may have occurred in nearshore gillnet fisheries prior to the legislative ban in 1992, which removed gillnets from state waters within three miles of shore.

4.3.4.6.3 Sampling Results

Salema larvae comprised 3.4% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period (**Table 4-2**). Although salema ranked as the eighth highest mean concentration of entrained fish larvae (**Table 4-2**), it was only collected in substantial numbers during a single entrainment survey in late August 2004 (**Figure 4-22a**). The concentrations during this survey (>300 per 1,000 m^3), however, were high enough to make it a notable species in the overall annual sampling. It was present in much lower abundances at the source water stations in July and August 2004 (**Figure 4-22b**). This indicates a strong inshore distribution and a highly seasonal reproduction period.

The length frequency distribution of measured salema larvae (**Figure 4-23**) shows an extremely limited size range dominated by recently hatched larvae, based on the reported hatch length of 2.2 mm (0.09 in) NL (Moser 1996). The mean, maximum, and minimum sizes for the measurements were 2.0, 2.6, and 1.7 mm (0.08, 0.1, and 0.07 in), respectively.

4.3.4.6.4 Impact Assessment

Because no salema larvae were collected in the entrainment samples and source water samples during the same survey, proportional losses were not able to be calculated for the *ETM* modeling. Salema larvae were present in the entrainment samples during the week previous to the final source water survey, but the modeling methods are based on a comparison of paired larval concentrations in the entrainment and source water from the same surveys. The lack of co-occurrence further highlights the high temporal and spatial variation of these larvae.

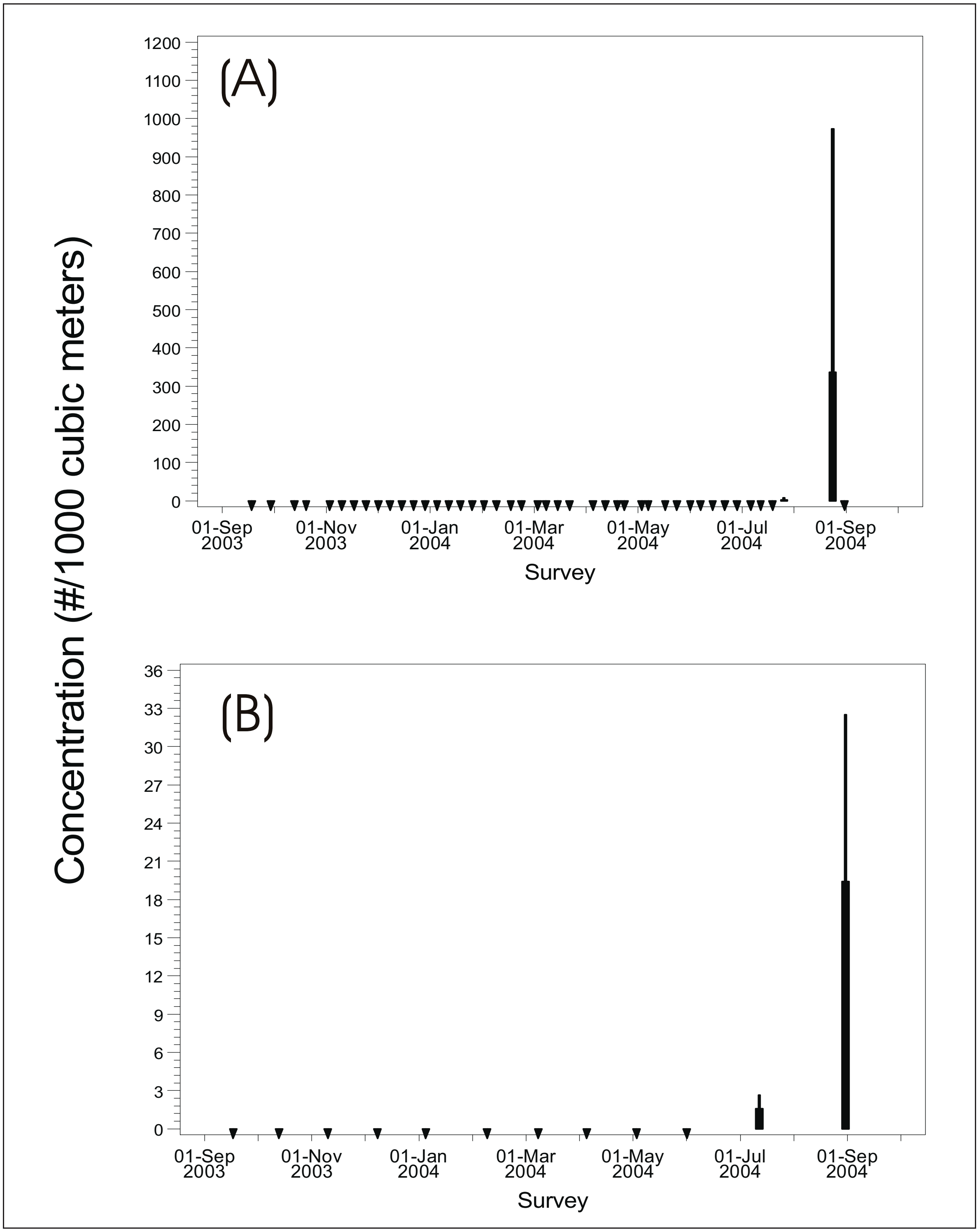

Figure 4-22. Survey mean concentration (#/1,000 m^3) of salema larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no salema larvae were collected.

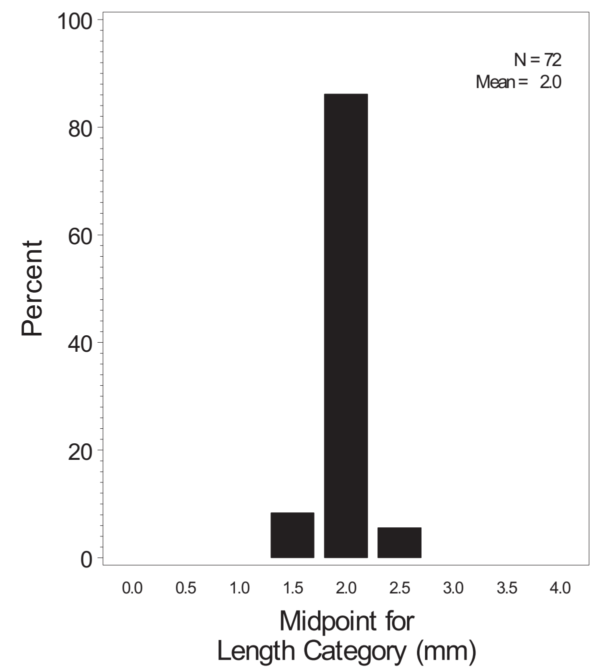

Figure 4-23. Length frequency distribution (mm) of salema larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.7 Combtooth Blennies (*Hypsoblennius spp.*)

Combtooth blennies (*Hypsoblennius spp.*) are all relatively small fishes that typically grow to a total length of less than 200 mm (7.9 in) (Moser 1996). Most have blunt heads that are topped with some arrangement of cirri (Moyle and Cech 1988, Moser 1996) and their bodies are generally elongate and without scales. Combtooth blennies are represented along the California coast by three members of the genus *Hypsoblennius*: bay blenny (*H. gentilis*), rockpool blenny (*H. gilberti*), and mussel blenny (*H. jenkinsi*). These species co-occur throughout much of their range although they occupy different habitats. The bay blenny is found along both coasts of Baja California and up the California coast to as far north as Monterey Bay, (Miller and Lea 1972, Robertson and Allen 2002). They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls (Stephens 1969, Stephens et al. 1970). The rockpool blenny occurs from Magdalena Bay, Baja California to Point Conception, California (Miller and Lea 1972, Stephens et al. 1970). They occur mainly along shallow rocky shorelines and kelp forests along the outer coast. The range of the mussel blenny extends from Morro Bay to Magdalena Bay, Baja California and in the northern Gulf of California (Tenera 2001, Robertson and Allen 2002). It is only found subtidally and inhabits mussel beds, the empty drill cavities of boring clams, barnacle tests, or in crevices among the vermiform snail tubes *Serpulorbis* spp. (Stephens 1969, Stephens et al. 1970).

The three species of *Hypsoblennius* found in California waters are morphologically similar as early larvae (Moser 1996, Ninos 1984). For this reason most *Hypsoblennius* identified in HBGS plankton collections were identified as *Hypsoblennius* spp. Certain morphological features (e.g., preopercular spines) develop at larger sizes and allow taxonomists to identify some larvae to the species level.

4.3.4.7.1 Reproduction, Age, and Growth

Female blennies mature quickly and reproduce within the first year, reaching peak reproductive potential in the third year (Stephens 1969). The spawning season typically begins in spring and may extend into September (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments (Moser 1996). Males are responsible for tending the nest and developing eggs. Females spawn 3–4 times over a period of several weeks (Stephens et al. 1970). Males guard the nest aggressively and will often chase the females away; however, several females may occasionally spawn with a single male. The number of eggs a female produces varies proportionately with size (Stephens et al. 1970). The mussel blenny spawns approximately 500 eggs in the first reproductive year and up to 1,500 eggs by the third year (Stephens et al. 1970). Total lifetime fecundity may be up to 7,700 eggs (Stephens 1969).

Larvae are pelagic and hatch at a size of 2.3–2.6 mm (0.09–0.10 in) (Moser 1996). The planktonic phase for *Hypsoblennius* spp. larvae may last for 3 months (Stephens et al. 1970, Love 1996). *Hypsoblennius* larvae are visual swimmers (Ninos 1984). Captured larvae released by divers have been observed to orient to floating algae, bubbles on the surface, or the bottoms of boats or buoys. The size at settlement ranges from 12–14 mm (0.5–0.6 in). After the first year mussel and bay blenny averaged 40 and 45 mm (1.6 and 1.8 in) TL, respectively (Stephens et al. 1970). The bay blenny grows to a slightly larger size and lives longer than the mussel blenny, reaching a size of 15 cm (5.9 in) and living for 6–7 years (Stephens 1969, Stephens et al. 1970, Miller and Lea 1972). Mussel blenny grows to 13 cm (5.1 in) and has a life span of 3–6 years (Stephens et al. 1970, Miller and Lea 1972). Male and female growth rates are similar.

4.3.4.7.2 Population Trends and Fishery

There is no fishery for combtooth blennies and therefore no records on adult population trends based on landings data.

4.3.4.7.3 Sampling Results

Combtooth blenny larvae comprised 2.1% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period (**Table 4-2**). Combtooth blenny concentrations at the entrainment and source water stations peaked in summer (June–August 2004) and were present in the study area throughout the year (**Figures 4-24a** and **b**). Maximum concentrations were recorded at the entrainment station in late June 2004 (105 per 1000 m^3), and source water concentrations peaked in late August 2004 (66 per 1000 m^3).

The length frequency distribution for a representative sample of combtooth blenny larvae is presented in **Figure 4-25**. The mean, maximum and minimum lengths were 2.2, 4.1, and 1.6 mm (0.09, 0.16, and 0.06 in), respectively. The majority of the larvae were recently hatched based on a reported hatch size of 2.5 mm (0.1 in) (Moser 1996).

4.3.4.7.4 Impact Assessment

The following sections present the results for demographic and empirical transport modeling of potential desalination system effects on combtooth blennies. Species-specific life history information for combtooth blennies is scarce. Larval survival was estimated using data from Stephens (1969) and Stevens and Moser (1982). There was enough information on reproduction to parameterize the *FH* demographic model, but not to calculate the *AEL* model. Larval growth was estimated from information from Stevens and Moser (1982).

Fecundity Hindcasting (*FH*)

The annual entrainment estimate for combtooth blenny larvae was used to estimate the number of breeding females needed to produce the entrained larvae. No estimates of egg survival for combtooth blenny were available, but because egg masses are attached and guarded by the male (Stephens et al. 1970), egg survival is probably high and was assumed to be 100%. The mean length for larval combtooth blenny larvae in entrainment samples was 2.2 mm (0.09 in). A larval growth rate of 0.20 mm/day (0.08 in/day) was derived from growth rates using data in Stevens and Moser (1982). We have used the length at the 10th percentile of measurements with the mean length to calculate the average age at entrainment for many of the fishes analyzed for this report, but due to the small differences between the 10th percentile (2.0 mm [0.08 in]) and the mean, a calculated hatch size of 1.9 mm (0.07 in) was used to estimate that the mean age at entrainment was 1.5 days. A daily survival rate of 0.89 computed from Stephens (1969) was used to calculate survival to the average age at entrainment as $0.89^{1.5} = 0.84$. An average batch fecundity estimate of 550 eggs was based on data from Stephens (1969), and an estimate of 2.3 spawns per year based on information from Stevens and Moser (1982) were used to calculate an annual fecundity of 1,281 eggs. An average longevity for mussel blenny of 3–6 yr from Stephens (1969) and an age of maturation of 0.4 yr from Stevens and Moser (1982) were used in the model.

The estimated numbers of adult female combtooth blennies whose lifetime reproductive output would be potentially entrained annually as a result of the desalination plant operation was 1,225 (**Table 4-27**). This was based on an annual entrainment of about 2.15 million larvae.

Table 4-27. Results of *FH* modeling for combtooth blenny larvae. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	1,225	1,065	293	5,122	4,829
Total Entrainment	2,148,242	173,938	1,062*	1,388*	326*

* Calculated using the standard error of the total entrainment estimate.

Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for combtooth blenny was based on the lengths of entrained larvae. The difference between the lengths of the calculated hatch length of 1.9 mm (0.07 in) and the length of the 95th percentile (2.7 mm [0.11 in]) was used with a growth rate of 0.20 mm/day (0.01 in/day) to estimate that combtooth blenny larvae were vulnerable to entrainment for a period of about 5.2 days.

The monthly estimates of proportional entrainment (*PE*) for combtooth blennies for the September 2003–August 2004 period varied among surveys and ranged from 0 to 0.00632 (**Table 4-28**). The average estimate of 0.00075 was affected by the large *PE* estimate for February 2004, which occurred when the proportion of blennies in the source waters were low. A weighted average, similar to the calculation for P_M, would reduce the value. This would place the average *PE* very close to the ratio of the projected HBDF daily flow to source water volumes of 0.00063 indicating that the volumetric ratio could be used to approximate the daily entrainment mortality. While the largest *PE* estimate was calculated for the February survey, the largest proportion in the source population occurred during the August survey (f_i = 0.42 or 42%). The small *PE* estimate for the August survey (0.00007) indicates that larvae were not abundant at the entrainment station during this survey (**Figure 4-24a**). The results also show that there were several surveys when blenny larvae were collected at the source water stations, but not at the entrainment stations.

Only the estimate for alongshore transport was calculated for blennies since these are primarily nearshore fishes and the larvae entrained at HBGS are probably from the embayments north and south of the plant. The estimates of P_M using alongshore current displacement was 0.00065 or 0.065% (**Table 4-29**). The P_S estimate indicate that the ratio of the sampled source water to the total population was 57.0%. The alongshore estimate of P_M was extrapolated over a shoreline distance of 18.3 km (11.4 mi).

Table 4-28. *ETM* data for combtooth blenny larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0	0	0.04350	0.02820
13-Oct-03	0	0	0.03255	0.03161
10-Nov-03	0.00127	0.00243	0.06645	0.05730
8-Dec-03	0.00050	0.00104	0.03080	0.02040
5-Jan-04	0.00040	0.00088	0.02438	0.02325
9-Feb-04	0.00632	0.02397	0.00138	0.00447
8-Mar-04	0	0	0	0
5-Apr-04	0	0	0.00147	0.00393
3-May-04	0	0	0.02012	0.01690
1-Jun-04	0.00021	0.00029	0.12027	0.06204
12-Jul-04	0.00025	0.00037	0.23727	0.17700
31-Aug-04	0.00007	0.00010	0.42181	0.16879
Average =	**0.00075**			

Table 4-29. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for combtooth blenny. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.5697 (18.3)	0.00065	0.26565	0.26631	0
Offshore Extrapolated		not calculated			

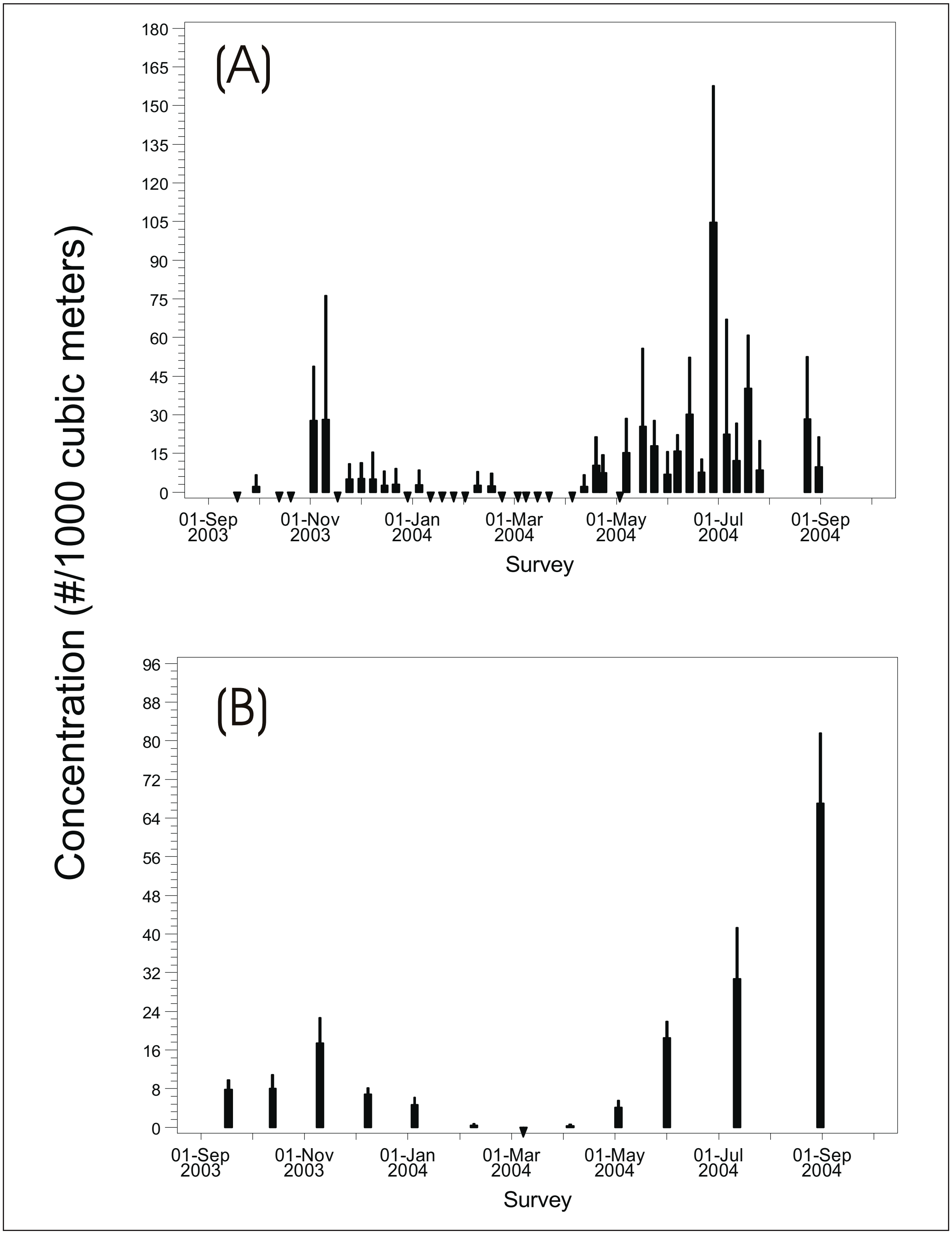

Figure 4-24. Survey mean concentration (#/1,000 m^3) of combtooth blenny larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no combtooth blenny larvae were collected.

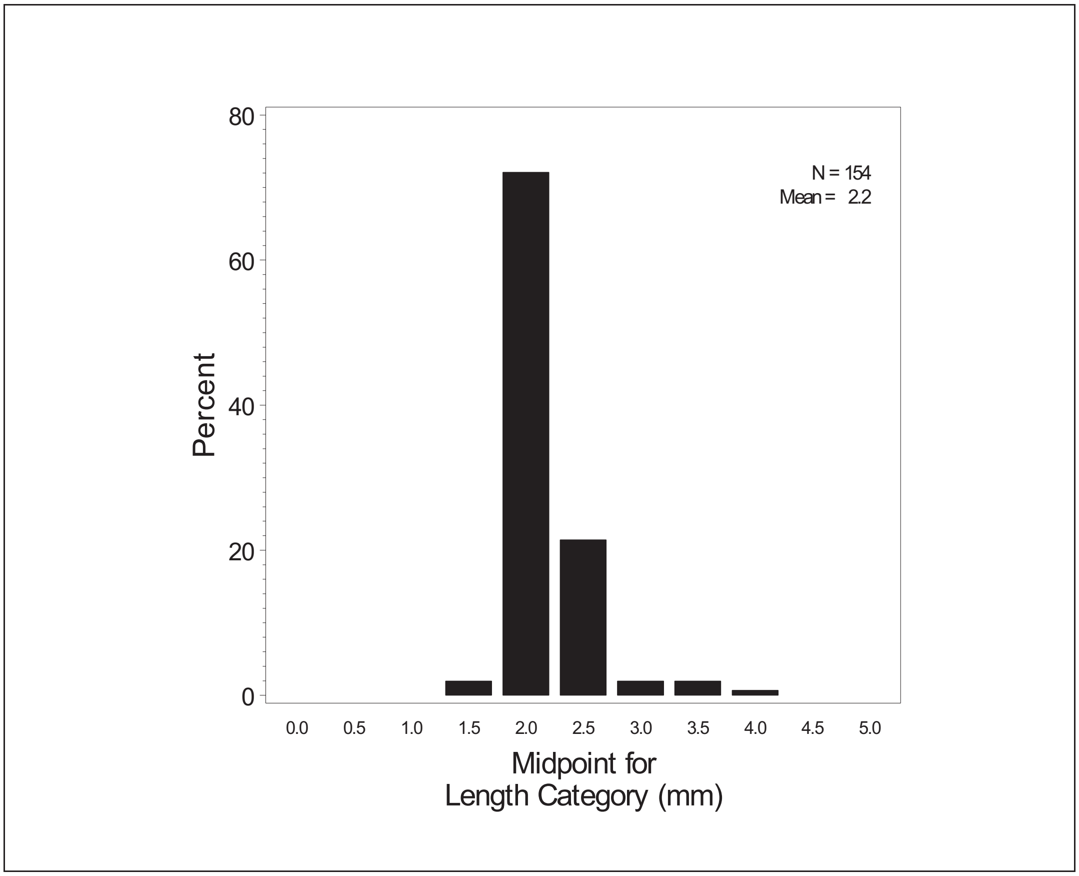

Figure 4-25. Length frequency distribution (mm) of combtooth blenny larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.8 Black Croaker (*Cheilotrema saturnum*)

Black croaker (*Cheilotrema saturnum*) is a member of the drums and croakers family (Sciaenidae) and ranges from Point Conception, California to central Baja California (including the Gulf of California) in depths from 3–50 m (9.8-164 ft) (Limbaugh 1961, Miller and Lea 1972). Black croaker is common to open-coast, shallow rocky reefs and kelp beds (Limbaugh 1961, Allen 1985) with large adults occupying shelters within the reef structure and smaller individuals typically occurring above the sand substrate in and around the reef (Limbaugh 1961).

4.3.4.8.1 Reproduction, Age, and Growth

Black croaker is an oviparous broadcast spawner with pelagic eggs and larvae (Moser 1996). Greater than 50% of both males and females are reproductively mature by 150 mm (5.9 in) SL, or approximately one year of age (Miller et al. 2009). Spawning is most prevalent in the late spring to summer months, with a peak in June and July based on histological examination (Goldberg 1981) and seasonal gonosomatic index (GSI) analysis (Miller et al. 2009). Late-stage larvae have been collected as early as July (Miller et al. 2009), with regular collections from August through October (Limbaugh 1961, Moser 1996). Spawning populations were found to be statistically skewed towards males at a ratio of 1.22:1 (male:female), with each sex represented in all size and age classes (Miller et al. 2009).

Moser (1996) reported newly hatched black croaker larvae to be 1.5 mm (0.06 in) NL. Flexion occurs at approximately 5.6 mm (0.22 in) NL and transformation occurs at standard lengths in excess of 11 mm (0.43 in) (Moser 1996). Black croaker grow rapidly during the first six years, attaining an average length of 200 mm (7.87 in) SL before growth rates slow (Miller et al. 2009). Black croaker reportedly grows to 380 mm SL (14.9 in) (Miller and Lea 1972) and can live to 22 years old with no significant differences in the growth rates between males and females (Miller et al. 2009). The strongest recruitment year within the last decade occurred in 1997, which corresponded to the highest sea surface temperature in the same time period (Miller et al. 2009).

4.3.4.8.2 Population Trends and Fishery

Historically, black croaker has been the third most abundant croaker species among impingement samples at southern California coastal generating stations since 1976, surpassed only by white croaker and queenfish (Herbinson et al. 2001). Long-term trends in impingement observations indicate an overall declining abundance, with a minor upturn in 1997. Currently, no commercial fisheries target black croaker, and only incidental catches occur in the recreational fishery.

4.3.4.8.3 Sampling Results

Black croaker larvae comprised 2.1% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period (**Table 4-2**). Black croaker larvae ranked 11th in mean concentration in entrainment samples (5.41 per 1,000 m^3; **Table 4-2**) and 19th in the source water samples (1.90 per 1,000 m^3; **Table 4-4**). They were collected from April through August 2004 with peak concentrations recorded in August in both the entrainment and source water samples (**Figure 4-26**). The highest entrainment concentrations occurred in late August when average concentrations exceeded 160 larvae per 1,000 m^3.

The length frequency distribution of measured black croaker larvae show an extremely limited size range dominated by recently hatched larvae based on the reported hatch length of 1.5 mm (0.06 in) NL (Moser 1996) (**Figure 4-27**). The mean, maximum, and minimum sizes for the measurements were 2.1, 11.5, and 1.5 mm (0.08, 0.45, and 0.06 in), respectively. A larval growth rate of 0.20 mm/day (0.008 in/day) for white croaker (Murdoch et al. 1989b) was used with the difference in the lengths of the 10th (1.6 mm [0.06 in]) and 95th (2.9 mm [0.11 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 7 days. The estimated duration of the egg stage of 2 days from Watson (1982) was added to the larval duration for a total duration of approximately 9 days.

4.3.4.8.4 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on black croaker larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of information on life history necessary to parameterize the models.

Empirical Transport Model (*ETM*)

Only two *PE* estimates were calculated for black croaker (**Table 4-30**). As shown in **Figure 4-26** these estimates were not necessarily reflective of actual black croaker abundances because the highest abundance at the entrainment station occurred during a survey when the source water stations were not sampled. The values of f_i show that almost 60% of the black croaker larvae were collected during source water surveys when no entrainment occurred. In addition, the *PE*s were calculated from surveys that represent two separate spawning seasons. The two P_M estimates calculated from these estimates (**Table 4-31**) were both low reflecting the short period of time (9 days) that the larvae were exposed to entrainment. The estimate of the shoreline transport over the 9 days was 55.1 km (34.2 mi).

Table 4-30. *ETM* data for black croaker larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0.00047	0.00115	0.09932	0.13513
13-Oct-03	0	0	0	0
10-Nov-03	0	0	0	0
8-Dec-03	0	0	0	0
5-Jan-04	0	0	0	0
9-Feb-04	0	0	0	0
8-Mar-04	0	0	0	0
5-Apr-04	0	0	0	0
3-May-04	0	0	0.11678	0.11218
1-Jun-04	0	0	0.11582	0.14993
12-Jul-04	0	0	0.36378	0.22890
31-Aug-04	0.00015	0.00032	0.30430	0.19281
Average =	**0.00005**			

Table 4-31. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for black croaker. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1896 (55.1)	0.00021	0.37820	0.37841	0
Offshore Extrapolated	0.1143	0.00020	0.37819	0.37839	0

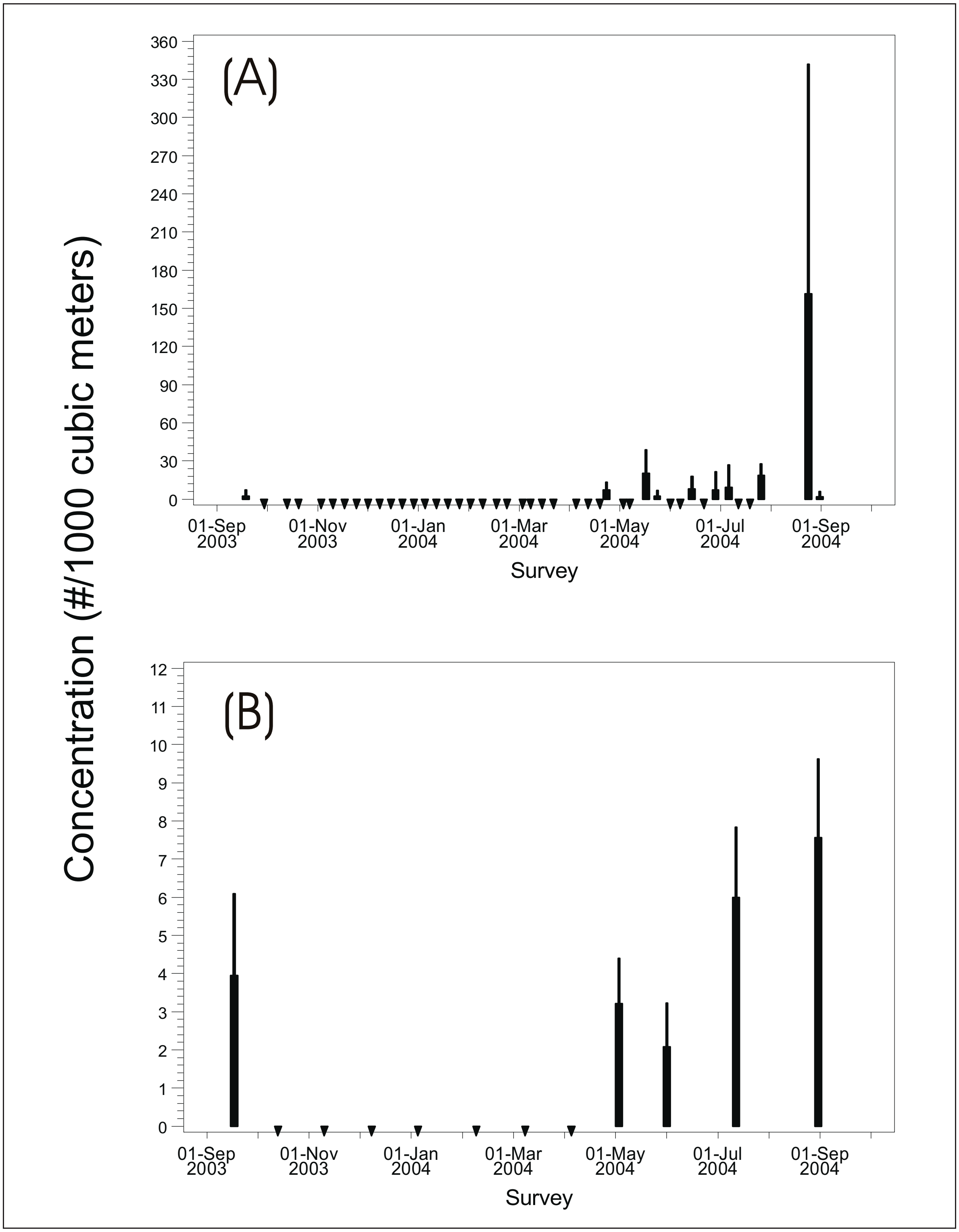

Figure 4-26. Survey mean concentration (#/1,000 m^3) of black croaker larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no black croaker larvae were collected.

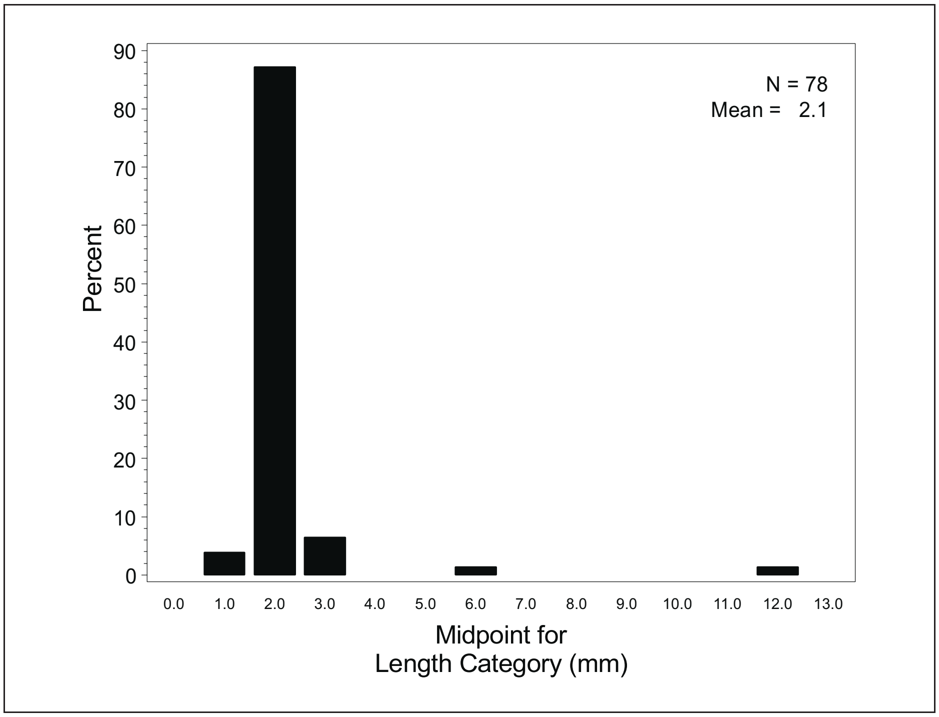

Figure 4-27. Length frequency distribution (mm) of black croaker larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.9 Diamond Turbot (*Pleuronichthys guttulatus*)

Diamond turbot (*Pleuronichthys guttulatus*) is classified in the family of right-eyed flatfishes (Pleuronectidae). It is one of twenty pleuronectid species that occur off California, and ranges from Cape San Lucas, Baja California to Cape Mendocino, California (Eldridge 1975). An isolated population has also been reported from the upper Gulf of California (Miller and Lea 1972). This species occurs on muddy or sandy substrates in bays or along nearshore coastal areas. It generally lives in water depths shallower than 50 m (164 ft), and is most common at depths less than 10 m (32.8 ft) (Lane 1975).

4.3.4.9.1 Reproduction, Age, and Growth

Little is known of the reproductive habits of the diamond turbot. Females become sexually mature at two to three years (Fitch and Lavenberg 1975), but no equivalent information is available concerning the males. Both sexes are sexually mature at a total length of 16.5 cm (6.5 in) (Love 1996). Spawning occurs year-round and appears to peak during the winter months (Eldridge 1975). Eggs collected in San Francisco Bay averaged 0.8 mm (0.031 in) in diameter (Eldridge 1975).

The largest diamond turbot reported in the literature was 46 cm (18 in) TL (Lane 1975). The maximum age for this species, based on otoliths and scales, is about eight years (Love 1996, Fitch and Lavenberg 1975). Newly hatched larvae collected in San Francisco Bay averaged

1.6 mm (0.06 in) NL (Eldridge 1975). Larvae are planktonic and settle to the bottom in shallow water after about five to six weeks. Standard length at the time of settlement is about 1.1-1.2 cm (0.43-0.47 in) (Eldridge 1975, Love 1996). Early growth rates appear to be similar to other flatfishes including the California halibut (*Paralichthys californicus*). Gadomski et al. (1990) calculated the growth rate to flexion of California halibut to be 0.23 mm/day (0.01 in/day). Total length of diamond turbot at one year is about 14 cm (5.5 in) (Lane 1975).

4.3.4.9.2 Population Trends and Fishery

Diamond turbot makes up a minor portion of the California marine sport fishery (Leos 2001). They are taken by anglers fishing from the shore, piers, or boats in shallow bays and estuaries. This species has little commercial importance but is taken occasionally as part of the incidental catch. It is usually reported under the grouping of ‘turbot’ along with several other flatfish species. None was reported as being landed in the Los Angeles region during 2007–2008 (PacFIN 2009).

4.3.4.9.3 Sampling Results

Diamond turbot larvae comprised 1.6% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period (**Table 4-2**). The estimated mean entrainment per survey was variable, ranging from zero to about 100 diamond turbot larvae per 1,000 m^3 (**Figure 4-28a).** Diamond turbot larvae were present during many of the surveys with a pronounced peak during August 2004. The peak concentration at the source water stations occurred in October 2003 (**Figure 4-28b**).

The length frequency distribution of measured diamond turbot larvae showed that the majority of were recently hatched based on the reported hatch length of 1.6 mm (0.06 in) SL (Eldridge 1975) (**Figure 4-29**). The mean, maximum, and minimum sizes for the measurements were 2.3, 4.8, and 1.3 mm (0.09, 0.19, and 0.05 in), respectively. A larval growth rate of 0.23 mm/day (0.01 in/day) calculated from data in Gadomski et al. (1990) for California halibut was used with the difference in the lengths of the 10th (1.6 mm [0.06 in]) and 95th (3.9 mm [0.15 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 13 days. This was added to the estimated egg duration of 2 days for a total period of 15 days.

4.3.4.9.4 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on diamond turbot larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of information on life history necessary to parameterize the models.

Empirical Transport Model (ETM)

The *PE* estimates for diamond turbot ranged from 0 to 0.00632 (**Table 4-32**). The average *PE* (0.00065) is very close to the ratio of the projected HBDF daily flow to source water volumes of 0.00063 indicating that the volumetric ratio could be used to approximate the daily entrainment mortality. The values of f_i indicate that diamond turbot larvae were present throughout much of the year in the source water and there were several surveys when they were present at the source water stations but not collected at the entrainment station. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 15-day period of exposure calculated using offshore extrapolated densities (0.00060 [0.06%]) is less than the estimate calculated using alongshore current displacement (0.00082 [0.08%]) because the effects of entrainment are spread over a larger population for the offshore extrapolated estimate (**Table 4-33**). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 21.1% and 15.8%, respectively, and the alongshore estimate was extrapolated over a shoreline distance of 49.4 km (30.7 mi).

Table 4-32. *ETM* data for diamond turbot larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0	0	0.07266	0.07101
13-Oct-03	0.00036	0.00047	0.20314	0.10636
10-Nov-03	0.00049	0.00112	0.08881	0.09327
8-Dec-03	0	0	0.03104	0.04430
5-Jan-04	0.00024	0.0005	0.19283	0.11089
9-Feb-04	0	0	0.04220	0.05032
8-Mar-04	0.00034	0.00076	0.13051	0.11381
5-Apr-04	0.00632	0.02397	0.00564	0.01816
3-May-04	0	0	0.08152	0.07454
1-Jun-04	0	0	0	0
12-Jul-04	0	0	0	0
31-Aug-04	0	0	0.15164	0.11536
Average =	**0.00065**			

Table 4-33. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for diamond turbot. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.2114 (49.4)	0.00082	0.27329	0.27411	0
Offshore Extrapolated	0.1577	0.00060	0.27296	0.27356	0

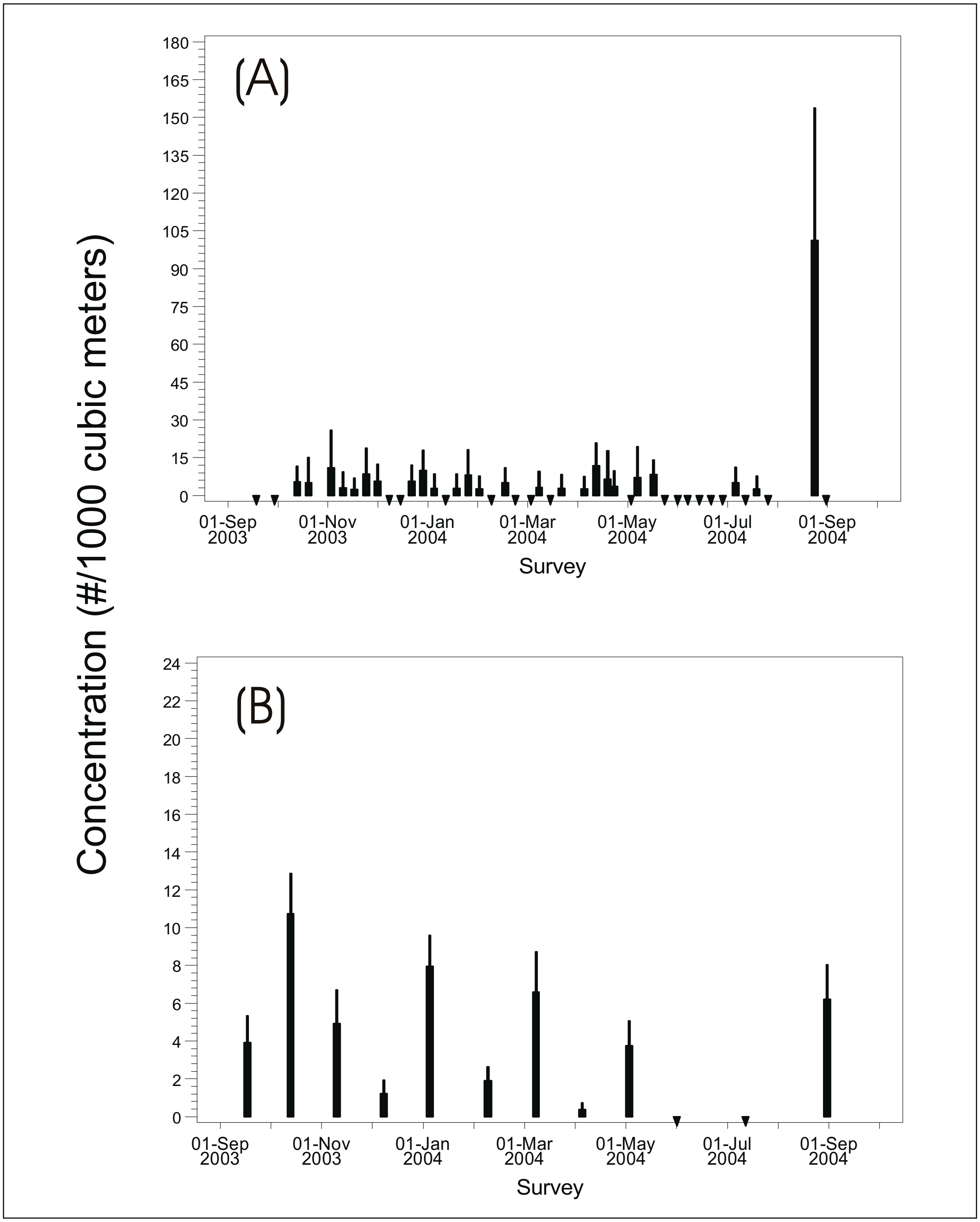

Figure 4-28. Survey mean concentration (#/1,000 m^3) of diamond turbot larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no diamond turbot larvae were collected.

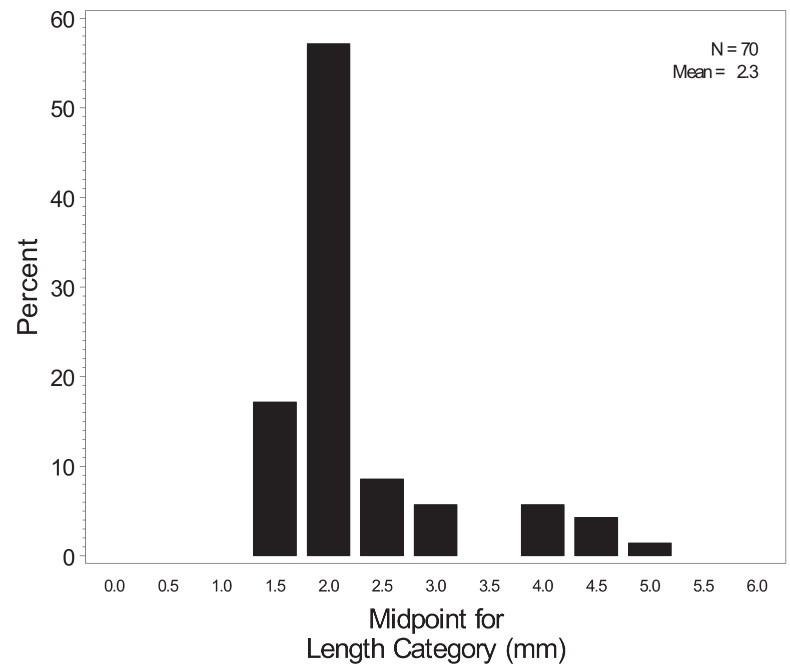

Figure 4-29. Length frequency distribution (mm) of diamond turbot larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.10 California Halibut (*Paralichthys californicus*)

California halibut (*Paralichthys californicus*) is an important part of California's commercial and recreational fisheries (Starr et al. 1998, Kramer and Sunada 2001). It ranges from northern Washington to Bahia Magdalena, southern Baja California and is found from very shallow nearshore waters in bay nursery grounds to depths of at least 185 m (607 ft) (Miller and Lea 1972, Haaker 1975). Juveniles and adults typically occur on sandy sediments at depths less than 30 m (98.5 ft) but sometimes concentrate near rocks, algae, or Pacific sand dollar (*Dendraster excentricus*) beds (Feder et al. 1974). As with other flatfishes, they frequently lie buried or partially buried in the sediment. Newly settled and juvenile halibut often occur in unvegetated shallow embayments and occasionally on the outer coast, suggesting that bays are an important nursery habitat for this species (Kramer and Sunada 2001).

4.3.4.10.1 Reproduction, Age, and Growth

California halibut is a broadcast spawner with eggs being fertilized externally. The spawning season is generally thought to extend from February to August with most spawning occurring in May (Frey 1971), although some fall spawning may also occur. The average number of eggs per spawn is 313,000–589,000 with an average reproductive output of approximately 5.5 million eggs per spawning season (Caddell et al. 1990). During spawning season females may release eggs every 7 days and the largest individuals may produce in excess of 50 million eggs per year (Caddell et al. 1990). Captive specimens were observed to spawn at least 13 times per season (Caddell et al. 1990). Halibut eggs are 0.7–0.8 mm (0.027-0.031 in) in diameter (Ahlstrom et al. 1984) and are most abundant in the water column at depths less than 75 m (246 ft) and within 6.5 km (4.0 mi) from shore (Kramer and Sunada 2001).

Upon hatching, the larvae (1.6–2.1 mm (0.06–0.08 in) NL [Moser 1996]) are pelagic (Frey 1971), and most abundant between Santa Barbara, California, and Punta Eugenia, Baja California Sur (Ahlstrom and Moser 1975) from January through April and June through August (Moser 1996). California halibut has a relatively short pelagic larval stage, from 20–29 days (Gadomski et al. 1990). Larval transformation occurs at a length of about 7.5–9.4 mm (0.3–0.4 in) SL (Moser 1996) at which time the young fish settle to the bottom, generally in bays but also occasionally in shallow substrates along the open coast (Haugen 1990). Kramer (1991) found that 6–10 mm (0.2–0.4 in) California halibut larvae grew <0.3 mm/day (0.012 in/day), while larger 70–120 mm (2.8–4.7 in) halibut grew about 1.0 mm/day (0.04 in/day). In a laboratory study, California halibut held at 16°C (60.8°F) grew to a length of 11.1 mm ± 2.61 (0.44 in ± 0.1) (SD) in two months from an initial hatch length of 1.9 mm (0.07 in) (Gadomski et al. 1990). After settling in the bays, the juveniles may remain there for about two years until they emigrate to the outer coast. Males mature at 2–3 years and 20–23 cm (7.9–9.0 in) SL; females mature at 4–5 years and 38–43 cm (14.9–16.9 in) SL (Fitch and Lavenberg 1971, Haaker 1975). Males emigrate out of the bays when they mature (i.e. at 20 cm [7.9 in]) but females migrate out as subadults at a length of about 25 cm (9.8 in) (Haugen 1990). Subadults remain nearshore at depths of 6–20 m (19.7–65.6 ft) (Clark 1930, Haaker 1975). California halibut may reach 152 cm (60 in) and 33 kg (73 lb) (Eschmeyer et al. 1983). Individuals may live as long as 30 years (Frey 1971).

4.3.4.10.2 Population Trends and Fishery

California halibut have a high commercial and recreational fishery value. The fishery for California halibut was reviewed by Kramer and Sunada (2001) and recent catch statistics are available through the PSMFC PacFIN (commercial) and RecFIN (recreational) databases. Historically, halibut have been commercially harvested by three principal gear types: otter trawl, set gill and trammel nets, and hook and line. Presently there are numerous gear, area, and seasonal restrictions that have been imposed on the commercial halibut fishery for management purposes. In southern California the average annual recreational catch during 2004–2008 was 61.6 metric tons (MT) (**Table 4-34**) while commercial landings in Los Angeles County alone averaged approximately 30 MT. During this time period, the largest commercial landings were in 2004 (51.0 MT), declining by approximately half during the next four years.

The size of the California halibut population may be limited by the availability of shallow-water nursery habitat, and a long-term decline in landings corresponds to a decline in these habitats in southern California associated with dredging and filling of bays and wetlands (Kramer and Sunada 2001). A fishery-independent trawl survey for halibut conducted in the early 1990s estimated that the southern California biomass was 6.9 million pounds (3.9 million adult fish) and the central California biomass was 2.3 million pounds (0.7 million fish) (Kramer and Sunada 2001).

Table 4-34. California halibut recreational fishing catch in southern California, and commercial fishing landings and ex-vessel value in Los Angeles County, 2004-2008. Data from RecFIN (2009) and PacFIN (2009).

Year	Estimated Recreational Catch (MT)	Estimated Recreational Catch (No.)	Commercial Landings (MT)	Ex-vessel Revenue ($)	Revenue per pound ($)
2004	92	29,000	51.0	$293,680	$5.15
2005	70	27,000	28.2	$244,362	$5.24
2006	68	33,000	25.4	$272,572	$4.87
2007	42	20,000	21.2	$296,200	$4.77
2008	36	19,000	25.9	$487,046	$4.33
Average	**61.6**	**25,600**	**30.3**	**$318,772**	**$4.87**

4.3.4.10.3 Sampling Results

California halibut larvae comprised approximately 1.5% of the total estimated annual entrainment of larval fishes during the 2003–2004 study period (**Table 4-2**). The estimated mean entrainment per survey was variable, ranging from zero to about 130 California halibut larvae per 1,000 m^3, with most larvae occurring from April through August (**Figure 4-30a**). The peak concentration at the entrainment station was recorded in June but the peak source water concentration occurred in August (**Figure 4-30b**).

The length frequency distribution of measured California halibut larvae showed a bi-modal size distribution which was dominated by recently hatched larvae, based on the reported hatch length of 1.6–2.1 mm (0.06–0.08 in) (Moser 1996), and a second peak at 6.0 mm (0.3 in) (**Figure 4-31**). The mean, maximum, and minimum sizes for the measurements were 2.1, 7.4, and 1.1 mm (0.08, 0.29, and 0.04 in), respectively. A larval growth rate of 0.23 mm/day (0.01 in/day) calculated from data in Gadomski et al. (1990) was used with the difference in the lengths of the first (1.1 mm [0.4 in]) and 95th (6.8 mm [0.3 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 25 days. The planktonic duration of the egg stage of 2 days (Gadomski et al. 1990, Emmett et al. 1991, Gadomski and Caddell 1996) was added to the larval duration for a total exposure period of 27 days.

4.3.4.10.4 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on California halibut larvae. Demographic model estimates of entrainment effects were calculated for the *FH* model.

Fecundity Hindcasting (*FH*)

The annual entrainment estimates for California halibut larvae were used to estimate the number of females at the age of maturity needed to produce the numbers of larvae over their lifetimes. An estimate of total egg survival of 0.5 was calculated from laboratory studies by Caddell et al. (1990) for an estimated planktonic duration of 2.19 days (Gadomski et al. 1990, Emmett et al. 1991, Gadomski and Caddell 1996). Daily larval survival for early stage larvae up to age 43.3 days was estimated at 0.95 from data in Kramer (1991). The mean length (2.1 mm [0.08 in]) and estimated hatch length of 1.3 mm (0.06 in) were used with a growth rate of 0.23 mm/day (0.01 in/day) calculated from data in Gadomski and Peterson (1988) to estimate that the larvae were exposed to entrainment for an average period of 3.5 days. The survival to the average age at entrainment was then calculated as $0.96^{3.5} = 0.86$. Total lifetime fecundity was estimated at 1,973,371 eggs using data in MacNair et al. (1991). This life history information was used to estimate that the numbers of entrained eggs and larvae were equivalent to the loss of only two female California halibut (**Table 4-35**). The results of the sensitivity analysis show that the greatest uncertainty associated with the estimates is associated with the life history parameters and not the entrainment estimate.

Table 4-35. Results of *FH* modeling for California halibut larvae. The upper and lower estimates are based on a 90% confidence interval of the mean.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	2	2	0	7	7
Total Entrainment	1,505,361	134,167	1*	2*	1*

* Calculated using the standard error of the total entrainment estimate.

Empirical Transport Model (*ETM*)

The *PE* estimates for California halibut were based on data collected during the 2003 and 2004 spawning periods. The values of f_i indicate increasing abundances of California halibut larvae in the source waters when the study was completed at the end of August 2004 (**Table 4-36**). This is not necessarily problematic if the assumption that the *PE* estimates are not related to changing abundances in source water is correct. The values of f_i also indicate that although there were surveys when no larvae were collected at the entrainment station (*PE*=0), *PE* estimates were available for the surveys when the majority of the halibut larvae were found in the source water samples. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 27-day period of exposure calculated using offshore extrapolated densities is less than the estimate calculated using alongshore current displacement because the effects of entrainment are spread over a much larger population for the offshore extrapolated estimate (**Table 4-37**). The P_s estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 13.7% and 2.7%, respectively, and the alongshore estimate was extrapolated over a shoreline distance of 76.2 km (47.3 mi).

Table 4-36. *ETM* data for California halibut larvae. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0	0	0.02009	0.01309
13-Oct-03	0	0	0.00987	0.01394
10-Nov-03	0.00043	0.00060	0.03617	0.03166
8-Dec-03	0	0	0	0
5-Jan-04	0	0	0.00616	0.01307
9-Feb-04	0	0	0.00158	0.00498
8-Mar-04	0	0	0.00873	0.01183
5-Apr-04	0	0	0.00599	0.00930
3-May-04	0.00041	0.00055	0.05424	0.02912
1-Jun-04	0.00013	0.00027	0.10875	0.08657
12-Jul-04	0.00027	0.00035	0.13504	0.06103
31-Aug-04	0.00003	0.00006	0.61338	0.16245
Average =	**0.00011**			

Table 4-37. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for California halibut. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1370 (76.2)	0.00026	0.20122	0.20148	0
Offshore Extrapolated	0.0273	0.00004	0.20072	0.20076	0

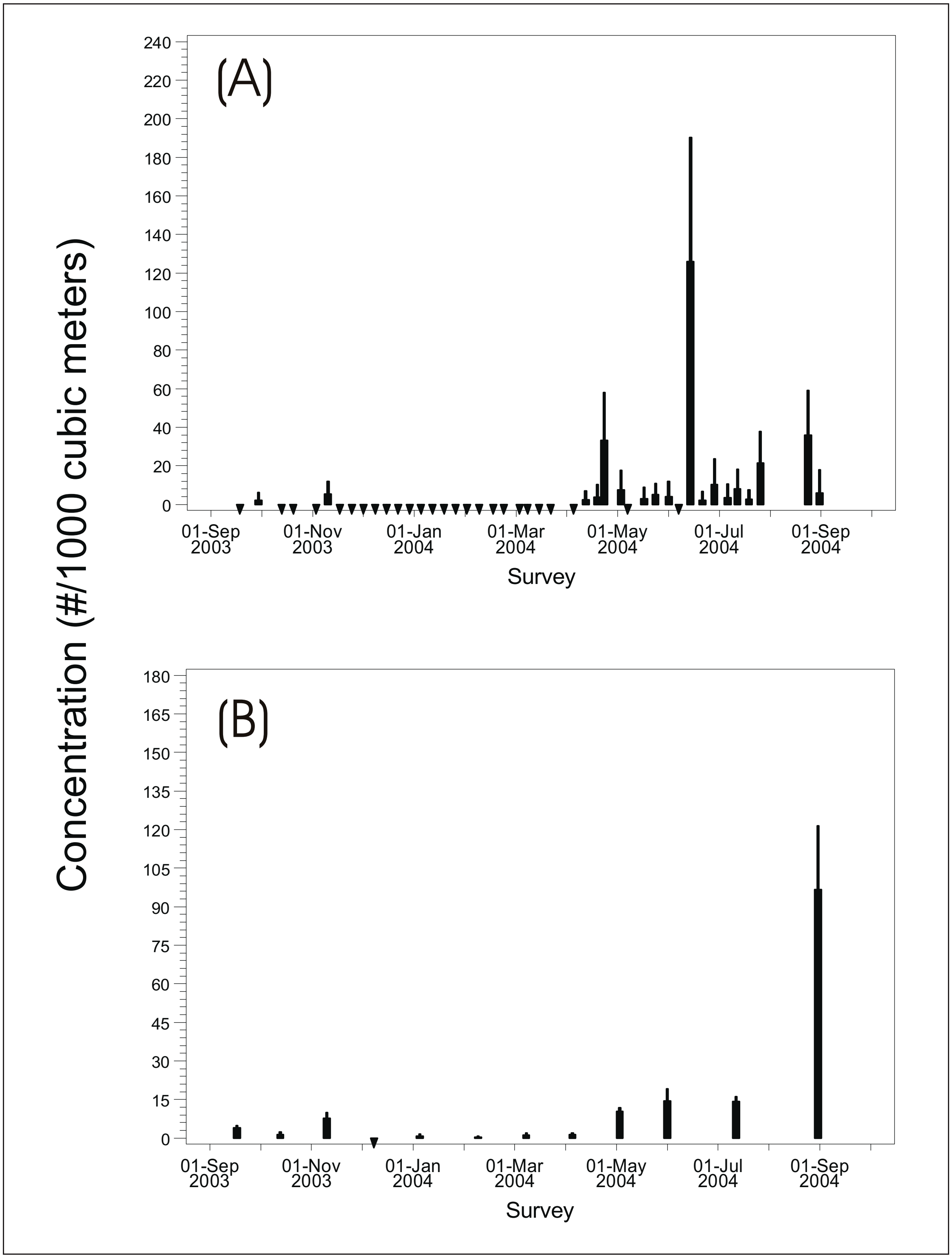

Figure 4-30. Survey mean concentration (#/1,000 m^3) of California halibut larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no California halibut larvae were collected.

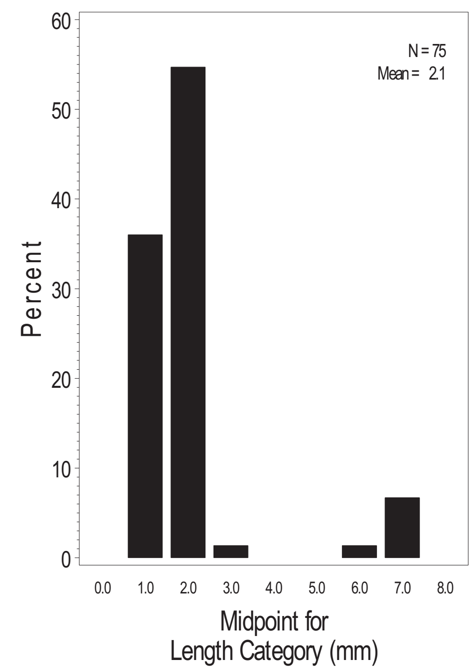

Figure 4-31. Length frequency distribution (mm) of Califorinia halibut larvae collected at the HBGS entrainment station from September 2003 through August 2004.

4.3.4.11 Rock Crabs (Cancridae) and Other Target Invertebrate Larvae

Five taxa of invertebrates with planktonic larvae were selected for analysis of potential impacts from entrainment during the 2003–2004 study. The taxa were Pacific sand crab (*Emerita analoga*), California spiny lobster (*Panulirus interruptus*), ridgeback rock shrimp (*Sicyonia ingentis*), market squid (*Doryteuthis opalescens*), and rock crabs (Cancridae). Of these, only rock crabs were collected in sufficient abundance in the entrainment samples to be considered for impact assessment.

Crabs of the family Cancridae are widely distributed in the coastal waters of the west coast of North America. They occur in intertidal and shallow subtidal habitats on both rock and sand substrate. All local species were formerly included under a single genus (*Cancer*), but were recently split into several genera based on fossil and molecular evidence (Schweitzer and Feldmann 2000). Four species of cancrid crabs (yellow crab [*Metacarcinus anthonyi*], Pacific rock crab [*Romaleon antennarius*], red rock crab [*Cancer productus*] and graceful crab [*Metacarcinus gracilis*]) may all occur in the vicinity of HBGS.

Each species in the genus has characteristic differences in distribution, preferred habitat, growth rates, and demographic parameters. For example, Pacific rock crab is a relatively large species (carapace width >155 mm [6.1 in]) that lives primarily on sand and mud substrates in estuarine and coastal shelf areas. Graceful crab is a smaller species (carapace width >130 mm [5.1 in]) associated with mixed rock-sand substrates in shallow outer coast habitats. Maximum clutch sizes can range from as many as 5,000,000 eggs in *M. anthonyi* to approximately 50,000 in pygmy rock crab (*Glebocarcinus oregonensis*) (Hines 1991). These types of differences imply that specific information on life history parameters cannot readily be generalized among cancrid species.

The nearshore distribution of crab larvae depends upon developmental stage. Shanks (1985) presented evidence that early stage larvae of rock crabs (probably yellow crab in his southern California study) generally occur near the bottom, in depths up to 80 m (262.5 ft); late stage larvae, however, were more abundant near the surface. He suggested that a combination of physical factors (primarily including wind-generated surface currents and tidally forced internal waves) caused megalopae to be transported shoreward. Late stage larvae (megalops) generally begin to recruit to the nearshore habitat in spring (Winn 1985).

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In one study in Monterey Bay, Graham (1989) found that Pacific rock crab Stage 1 zoea are most abundant close to shore and that subsequent zoeal stages tend to remain within a few kilometers of the coastline. The adult population primarily resides in relatively shallow rocky areas, and the nearshore retention of larvae in Graham's (1989) study was related to the formation of an oceanographic frontal zone in northern Monterey Bay that prevented substantial offshore transport during upwelling periods.

4.3.4.11.1 Reproduction, Age, and Growth

All species of cancrid crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and a pre-zoea larva emerges, beginning the planktonic life history phase. As in all crustaceans, growth progresses through a series of molts. The planktonic larvae advance through six stages of successive increases in size: five zoea (not including the brief pre-zoea stage) and one megalopal. After several weeks as planktonic larvae, the crabs metamorphose into the first crab stage (first instar) and settle out to begin their benthic life history phase. Maturity is generally attained within 1–2 years. Mature females mate while in the soft shell molt condition and extrude fertilized eggs onto the abdominal pleopods. Females generally produce one or two batches per year, typically in winter.

The main determinant of brood size and reproductive output in brachyuran crabs is body size, and the range of egg production in cancrid crabs generally reflects this relationship (Hines 1991). Yellow crab, the largest of the species found in the HBGS samples, produce on average 2.21 million eggs per brood. The next largest species, red rock crab, produces on average 877,000 eggs per brood. Pacific rock crab females seem to be an exception to this relationship because they are, on average, smaller than the red rock crab, yet can produce an average of 1.2 million eggs per batch. Graceful crab is the smallest of the four species living near HBGS and their average egg production per brood is 454,000. Female cancrid crabs on average produce a single batch per year, generally in the winter; however, due to occasional multiple spawnings, the average number of batches per year may be greater than one (Carroll 1982, Hines 1991).

Brown rock crab eggs require a development time of approximately 7–8 weeks from extrusion to hatching (Carroll 1982). Larval development in the brown rock crab was described by Roesijadi (1976). Eggs hatch into pre-zoea larvae that molt to first stage zoea in less than 1 hour. Average larval development time (from hatching through completion of the fifth stage) was 36 days at 13.8°C (56.8°F). Although some crabs molted to the megalops stage, none molted to the first crab instar stage, so the actual duration of the megalops stage is unknown. Based on a predicted megalops duration of approximately 12 days measured for the closely related yellow crab, the estimated length of time from hatching to settling for brown rock crab is approximately 48 days. Brown rock crab mature at an age of about 18 months post-settlement with a size of approximately 60 mm (2.4 in) carapace width and a weight of 73 g (Carroll 1982). Faster growth rates may occur in highly productive environments such as on the supporting members of offshore oil platforms and females may become reproductive in less than 1 year post-settlement (D. Dugan, Tenera Environmental, pers. comm.). Brown rock crab can probably live to a maximum age of about 6 yr. Size at recruitment to the fishery is approximately 125 mm (4.9 in) carapace width, at an age of 4 years for males and 4.5 years for females.

There are no published estimates of rock crab larval mortality. However, data from the abundance of Pacific rock crab zoea and megalops in the Diablo Canyon Power Plant 316(b) demonstration (Tenera 2000a) were used to estimate mortality between stages. First stage zoea of the taxa *R. antennarius*, *M. anthonyi*, and *M. gracilis* (combined because of uncertainties in identification) were substantially more abundant, on average, than all other stages combined. The proportions of each species of zoea stage 1 were derived by using the proportions of each species in zoea stage 2 that could be identified to species. An instantaneous larval mortality of 0.158/day was estimated by fitting an exponential curve to the estimated numbers of entrained concentrations of zoea stage 1 and megalops and using 38 days as the time between stages (i.e., 5 days and 43.3 days, respectively).

4.3.4.11.2 Population Trends and Fishery

Rock crabs are fished along the entire California coast with crab pots, though some landings are reported from set gill nets and trawls as well (CDFG 2004). Three species are harvested commercially: Pacific rock crab, red rock crab, and yellow crab. There is no commercial fishery for the graceful crab. The rock crab fishery is most important in southern California (from Morro Bay south), which produces a majority of the landings, and of lesser importance in northern areas of California where a fishery for the more desirable Dungeness crab takes place. Most rock crabs are landed alive for retail sale by fresh fish markets. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general "rock crab" category. From 1991 through 1999 state-wide rock crab landings (including claws) averaged 1.2 million lb/year (Parker 2001).

Regulations currently specify a minimum harvest size of 108 mm (4.25 in) carapace width. A small recreational fishery for rock crabs also exists, with a 102 mm (4.00 in) minimum carapace width and a personal bag limit of 35 crabs per day. Crabs are collected by divers or shore pickers with hoop nets and crab traps.

Recent catch statistics from the PSMFC PacFIN (commercial) database were examined for the years 2004–2008 for Los Angeles County. The average annual commercial catch and ex-vessel revenue from rock crab for the years 2004–2008 was approximately 49,200 kg (108,400 lb) and $155,000, respectively (**Table 4-38**). During this period the greatest catches were in 2007 and the smallest were in 2005.

Table 4-38. Rock crab commercial fishery landings (kilograms and pounds) and ex-vessel revenue in Los Angeles County, 2004-2008. Data from PacFIN (2009).

Year	Commercial Landings (kg)	Commercial Landings (lb)	Revenue ($)
2004	34,300	75,638	$109,536
2005	32,300	71,181	$105,941
2006	34,100	75,118	$112,994
2007	84,800	186,966	$253,217
2008	60,300	133,042	$194,491
Average	**49,160**	**108,389**	**$155,235**

4.3.4.11.3 Sampling Results

Yellow crab was the most abundant rock crab megalops in the entrainment samples followed by graceful crab, Pacific rock crab, and red rock crab (**Table 4-3**). In the source water samples yellow crab and graceful crab megalops were collected in nearly equal concentrations, followed by Pacific rock crab and red rock crab (**Table 4-5**). There was a strong seasonal occurrence in summer months with a periodicity of approximately six weeks and increasing amplitude through the August survey. Greatest concentrations occurred in July in the source water samples.

4.3.4.11.4 Impact Assessment

The following section presents the results for empirical transport modeling feedwater system effects on these combined species because they are not differentiated in catch records and all three species are similar and co-occur in the study area. There was not enough information available on mortality rates to parameterize the demographic models.

Empirical Transport Model (*ETM*)

The *PE* estimates for rock crabs range from 0 to 0.0041 (**Table 4-39).** The average *PE* (0.00064) is very close to the ratio of the projected HBDF daily flow to source water volumes of 0.00063 indicating that the volumetric ratio could be used to approximate the daily entrainment mortality. The values of f_i indicate that rock crab larvae were most abundant in the source water during the

June through August period with a peak in July. There were four surveys when larvae were collected at the source water stations, but were not collected at the entrainment station. The values of f_i indicate that these were periods when crab larvae were less abundant in the source water. Although the larval duration of the megalops stage is approximately 12 days based on laboratory rearing data of larvae cultured at 18°C (64.4°F) (Anderson and Ford 1976) a total larval duration of 45 days to account for entrainment of earlier zoeal stage larvae. The estimate of P_M for the 45-day period of exposure calculated using offshore extrapolated densities is less than the estimate calculated using alongshore current displacement because the effects of entrainment are spread over a larger population for the offshore extrapolated estimate (**Table 4-40**). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 10.4% and 1.9%, respectively, and the alongshore estimate was extrapolated over a shoreline distance of 100.3 km (62.3 mi).

Table 4-39. *ETM* data for cancrid crab megalops. Average *PE* estimate calculated from all surveys with $PE > 0$.

Survey Date	*PE* Estimate	*PE* Std. Err.	f_i	f_i Std. Err.
17-Sep-03	0	0	0	0
13-Oct-03	0	0	0.00241	0.00766
10-Nov-03	0	0	0	0
8-Dec-03	0	0	0.01801	0.03054
5-Jan-04	0.00407	0.00805	0.00908	0.01540
9-Feb-04	0	0	0.00235	0.00714
8-Mar-04	0	0	0	0
5-Apr-04	0	0	0.00299	0.00811
3-May-04	0.00168	0.00440	0.00899	0.01596
1-Jun-04	0.00060	0.00084	0.16365	0.14691
12-Jul-04	0.00098	0.00186	0.66245	0.23482
31-Aug-04	0.00039	0.00093	0.13007	0.15900
Average =	**0.00064**			

Table 4-40. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for cancrid crab megalops. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1040 (100.3)	0.00329	0.32611	0.32941	0
Offshore Extrapolated	0.0185	0.00217	0.32465	0.32681	0

5.0 Impingement Study

5.1 Introduction

From July 29, 2003 through July 20, 2004, impingement of fishes and macroinvertebrates, including shellfishes, was monitored each week at the AES Huntington Beach Generating Station (HBGS) as required by Conditions of Certification from the California Energy Commission (CEC). Cooling water for the HBGS is withdrawn from the ocean waters directly offshore the generating station through a submerged, velocity-capped intake. A total of eight circulating water pumps withdraw a maximum of approximately 1,919,000 m^3 (507 million gallons per day [mgd]) at HBGS Units 1–4.

Poseidon Resources is currently in the planning phases of constructing an ocean desalination plant on site at the HBGS. It is currently unknown what the estimated impingement mortality would be if the HBGS ceased operation of its circulating water pumps and Poseidon assumed seawater circulation solely for its desalination process. The objective of this evaluation of the MBC and Tenera (2005) data is to estimate the impingement mortality associated with seawater circulated only for the Huntington Beach Desalination Facility (HBDF), which would require a substantially lower volume of seawater (152 mgd) than is permitted for the HBGS (507 mgd). Also, as the HBDF will not generate waste heat similar to the operations of the HBGS, heat treatments to control biofouling will likely not occur. Therefore, the heat treatment impingement mortality recorded by MBC and Tenera (2005) is not included in this analysis. Rather, the analysis focuses on impingement data collected during normal HBGS operations.

This analysis focuses primarily on impingement effects on fishes. The HBGS intake is located offshore and withdraws seawater from the middle of the water column along a reach of sandy coastline. Although data on shellfish are presented, there are few shellfish, with the exception of squid and some crab species that can swim in the water column where they would be potentially subject to impingement. The majority of the shellfish impingement probably occurs from organisms living within the intake and forebay of the cooling system.

5.2 Methods

The impingement study was designed to estimate losses of fishes and shellfish due to operation of the HBGS cooling water system. The sampling methodologies were described in detail, including QA/QC procedures, in MBC and Tenera (2005). In summary, impingement samples were collected from the screening facility within the generating station on a weekly basis beginning July 29, 2003 and continuing through July 20, 2004. Once per week, impingement samples were collected for approximately a 24-hr period in coordination with generating station operations personnel. Twenty-four hours prior to each survey, the traveling screens were run and the accumulation container emptied. The screens remained stationary for a period of 24 hours before being operated for approximately 10 minutes, which is enough time for the traveling screens to complete one rotation and is sufficient to collect any impinged organisms from the forebay.

Impinged fishes, invertebrates, algae, and debris collected from the 24-hr samples were sorted, and fishes and macroinvertebrates were identified to species (whenever possible), enumerated, and batch-weighed. Standard length (SL) of up to 200 individual fishes of each species was measured, and sex of up to 50 individuals of selected species was determined by external morphology or inspection of gonads. Algae and shell debris were identified and batch-weighed. Station operation data (number of circulating water pumps operating, intake water temperature, and discharge water temperature) and general weather conditions were recorded during sampling. Of the macroinvertebrate species processed by MBC and Tenera (2005) only shellfish (generally defined as crustaceans and mollusks) were analyzed in the current assessment.

The total estimated impingement during normal operations was calculated by first calculating the impingement rate (numbers of individuals or biomass per cubic meter of HBGS-pumped water) using the total volume of cooling water flow over the sampling period. This rate was then multiplied by the total cooling flow over the usually seven-day survey period representative of the sampling date. To estimate total impingement for the HBDF, a daily intake flow volume of 152 (mgd) (575,380 m^3) was used for each day during the survey period. The annual totals for both estimates were calculated as the summation of the weekly estimates.

In addition to calculating total annual impingement based on the proportion of HBDF to normal HBGS flows, the total numbers of fishes collected during each survey were used to estimate annual totals based on an assumed linear relationship between flow rate and impingement. The impingement measurements and corresponding flows for each sampling date were analyzed using regression to obtain estimates of coefficients describing the relationship. These coefficients were then used to recalculate an estimate of the total annual impingement. The analysis was done in two ways: 1) with all of the surveys included and 2) with the data from the survey on January 27, 2004 removed due to the large number of juvenile queenfish (*Seriphus politus*) collected.

5.3 Impingement Results

The following section presents results from the July 29, 2003–July 20, 2004 sampling of normal operations impingement at HBGS, and the estimated impingement based on a 152 mgd flow rate for the desalination feedwater source. Data are presented by survey in MBC and Tenera (2005).

5.3.1 Fishes

Estimated annual impingement was calculated based on results of 52 weeks of impingement samples collected from July 29, 2003–July 20, 2004. A total of 12,692 fishes representing 36 species were estimated to have been impinged during normal operations from July 29, 2003–July 20, 2004 (**Table 5-1**). The highest normal operations abundance of fishes occurred during the January 27, 2004 survey when a large number of juvenile queenfish were impinged

(**Figure 5-1**). In addition to the large number of fishes collected from this one survey, there were slight seasonal peaks of fish abundance in September and October 2003 (mainly queenfish and northern anchovy [*Engraulis mordax*]) and in April and May 2004 (primarily queenfish and white croaker [*Genyonemus lineatus*]). The most abundant species overall were queenfish (82.5%), northern anchovy (6.5%), white croaker (2.2%), and shiner perch (*Cymatogaster aggregata*) (1.7%). Fish biomass for the survey year was an estimated 290 kg (639 lb). Biomass by survey is shown in **Figure 5-2**. Biomass was dominated by elasmobranchs, including Pacific electric ray (*Torpedo californica*; 44.7%), round stingray (*Urobatis halleri*; 6.0%), thornback (*Platyrhinoidis triseriata*; 5.5%), and bat ray (*Myliobatis californica*; 3.7%), and by some of the more abundant fish species, including queenfish (20.0%) and specklefin midshipman (*Porichthys myriaster*; 3.5%) (**Table 5-1**).

Estimated annual impingement for a 152 mgd HBDF intake volume totaled 4,853 fishes weighing 118 kg (260 lb) (**Table 5-2**). Queenfish accounted for 81.2% of the estimated total abundance (n = 3,939). An additional eight species accounted for nearly 15% of the estimated total (northern anchovy, white croaker, shiner perch, Pacific pompano [*Peprilus simillimus*], specklefin midshipman, white seaperch [*Phanerodon furcatus*], Pacific sardine [*Sardinops sagax*], and round stingray [*Urobatis halleri*]) (**Table 5-2**). Heavy-bodied fish species, which were typically impinged in lower abundances, accounted for substantially larger portions of the estimated impingement biomass. Pacific electric ray accounted for 41% of the total or 49 kg (108 lb). Queenfish, the only highly-abundant species among the five species with highest biomass, contributed an additional 22 kg (49 lb) or 18.9% to the total estimated biomass.

5.3.1.1 Flow Adjusted Estimates

Estimates of total annual impingement were also calculated using coefficients from linear and nonlinear regressions of flow rate and impingement. The coefficients from the linear regressions were used to calculate the estimated daily impingement rate, which was then multiplied by the daily flow of the HBDF and by 365 to obtain an annual estimate. The regressions of number and biomass for both the entire data set, and the data excluding the January 27, 2004 survey, all had negative intercepts resulting in daily impingement rates of less than zero when using a daily intake flow of 152 mgd—lower than any of the flows recorded during the sampling (**Figures 5-3** through **5-6**). Therefore, linear regression models using an intercept of zero were used in estimating annual impingement. The zero-intercept model is based on the fact that there is no impingement when flow is zero.

The low R^2 values from the linear regression analyses confirm only a weak relationship between impingement and intake flow (**Figures 5-3** through **5-6**). The impingement estimates based on extrapolation of survey data as weighted or unweighted averages are very similar in value since the survey periods used as the weights were usually seven days in length (**Table 5-3**). The estimates calculated using zero-intercept regression models bracket the estimates calculated using the unweighted and weighted average impingement rates.

A zero-intercept nonlinear model, fit to the data excluding the January 27, 2004 survey, showed slightly smaller variance of residuals than the zero-intercept linear model (**Figures 5-5** and **5-6**). The nonlinear model predicted a low impingement rate, 0.5 fish per day at 152 mgd.

Table 5-1. Estimated annual fish impingement abundance and biomass for normal operations at HBGS based on impingement data collected in 2003–2004 and actual cooling water flow rates.

Species	Common Name	Estimated Total Annual Abundance	Estimated Total Annual Biomass (kg)	Percent of Total Abund.	Percent of Total Biomass
Seriphus politus	queenfish	10,468	58.015	82.5	20.0
Engraulis mordax	northern anchovy	824	5.513	6.5	1.9
Genyonemus lineatus	white croaker	274	3.374	2.2	1.2
Cymatogaster aggregata	shiner perch	215	2.014	1.7	0.7
Peprilus simillimus	Pacific butterfish	131	2.096	1.0	0.7
Porichthys myriaster	specklefin midshipman	99	10.249	0.8	3.5
Phanerodon furcatus	white seaperch	80	0.485	0.6	0.2
Sardinops sagax	Pacific sardine	69	3.322	0.5	1.1
Urobatis halleri	round stingray	52	17.322	0.4	6.0
Leuresthes tenuis	California grunion	49	0.211	0.4	<0.1
Scorpaena guttata	California scorpionfish	35	5.528	0.3	1.9
Pleuronichthys ritteri	spotted turbot	35	2.438	0.3	0.8
Torpedo californica	Pacific electric ray	31	129.444	0.2	44.7
Hyperprosopon argenteum	walleye surfperch	30	0.498	0.2	0.2
Synodus lucioceps	California lizardfish	29	1.130	0.2	0.4
Pleuronichthys verticalis	hornyhead turbot	27	0.277	0.2	<0.1
Atherinopsis californiensis	jacksmelt	23	2.370	0.2	0.8
Cheilotrema saturnum	black croaker	21	0.330	0.2	0.1
Heterostichus rostratus	giant kelpfish	21	1.045	0.2	0.4
Myliobatis californica	bat ray	19	10.659	0.1	3.7
Platyrhinoidis triseriata	thornback	18	15.812	0.1	5.5
Leptocottus armatus	Pacific staghorn sculpin	17	0.870	0.1	0.3
Paralichthys californicus	California halibut	15	4.068	0.1	1.4
Citharichthys stigmaeus	speckled sanddab	14	0.043	0.1	<0.1
Embiotoca jacksoni	black perch	12	1.873	<0.1	0.6
Atractoscion nobilis	white seabass	11	0.135	<0.1	<0.1
Xenistius californiensis	salema	11	0.101	<0.1	<0.1
Porichthys notatus	plainfin midshipman	9	3.267	<0.1	1.1
Chromis punctipinnis	blacksmith	7	0.015	<0.1	<0.1
Girella nigricans	opaleye	7	4.274	<0.1	1.5
Ophidion scrippsae	basketweave cusk-eel	7	0.378	<0.1	0.1
Paralabrax nebulifer	barred sand bass	7	0.364	<0.1	0.1
Trachurus symmetricus	jack mackerel	7	0.030	<0.1	<0.1
Anchoa compressa	deepbody anchovy	6	0.032	<0.1	<0.1
Ophichthus zophochir	yellow snake eel	6	1.332	<0.1	0.5
Pleuronichthys guttulatus	diamond turbot	6	0.849	<0.1	0.3
	Total	**12,692**	**289.763**		
	Number of Species	**36**			

Table 5-2. Estimated annual fish impingement abundance and biomass adjusted proportionally for maximum HBDF desalination flow (152 mgd).

Species	Common Name	Estimated Total Annual Abundance	Estimated Total Annual Biomass (kg)	Percent of Total Abund.	Percent of Total Biomass
Seriphus politus	queenfish	3,939	22.271	81.2	18.9
Engraulis mordax	northern anchovy	298	1.944	6.1	1.7
Genyonemus lineatus	white croaker	127	1.497	2.6	1.3
Cymatogaster aggregata	shiner perch	85	0.808	1.7	0.7
Peprilus simillimus	Pacific pompano	53	0.848	1.1	0.7
Porichthys myriaster	specklefin midshipman	52	5.643	1.1	4.8
Phanerodon furcatus	white seaperch	36	0.196	0.7	0.2
Sardinops sagax	Pacific sardine	33	1.705	0.7	1.5
Urobatis halleri	round stingray	26	8.538	0.5	7.3
Leuresthes tenuis	California grunion	17	0.074	0.3	<0.1
Pleuronichthys ritteri	spotted turbot	16	0.859	0.3	0.7
Scorpaena guttata	California scorpionfish	13	2.164	0.3	1.8
Hyperprosopon argenteum	walleye surfperch	12	0.191	0.2	0.2
Torpedo californica	Pacific electric ray	12	48.722	0.2	41.4
Heterostichus rostratus	giant kelpfish	11	0.495	0.2	0.4
Pleuronichthys verticalis	hornyhead turbot	11	0.103	0.2	<0.1
Synodus lucioceps	California lizardfish	11	0.386	0.2	0.3
Atherinopsis californiensis	jacksmelt	9	0.943	0.2	0.8
Leptocottus armatus	staghorn sculpin	9	0.555	0.2	0.5
Citharichthys stigmaeus	speckled sanddab	8	0.024	0.2	<0.1
Myliobatis californica	bat ray	9	5.579	0.2	4.7
Cheilotrema saturnum	black croaker	8	0.143	0.2	0.1
Paralichthys californicus	California halibut	7	2.139	0.1	1.8
Porichthys notatus	plainfin midshipman	7	2.519	0.1	2.1
Embiotoca jacksoni	black perch	6	0.898	<0.1	0.8
Platyrhinoidis triseriata	thornback	6	5.767	<0.1	4.9
Atractoscion nobilis	white seabass	4	0.050	<0.1	<0.1
Ophidion scrippsae	basketweave cusk0eel	4	0.227	<0.1	0.2
Paralabrax nebulifer	barred sand bass	4	0.218	<0.1	0.2
Xenistius californiensis	salema	4	0.038	<0.1	<0.1
Chromis punctipinnis	blacksmith	3	0.007	<0.1	<0.1
Trachurus symmetricus	jack mackerel	3	0.013	<0.1	<0.1
Anchoa compressa	deepbody anchovy	3	0.013	<0.1	<0.1
Girella nigricans	opaleye	2	1.079	<0.1	0.9
Ophichthus zophochir	yellow snake eel	3	0.605	<0.1	0.5
Pleuronichthys guttulatus	diamond turbot	2	0.317	<0.1	0.3
	Total	**4,853**	**117.578**		
	Number of Species	**36**			

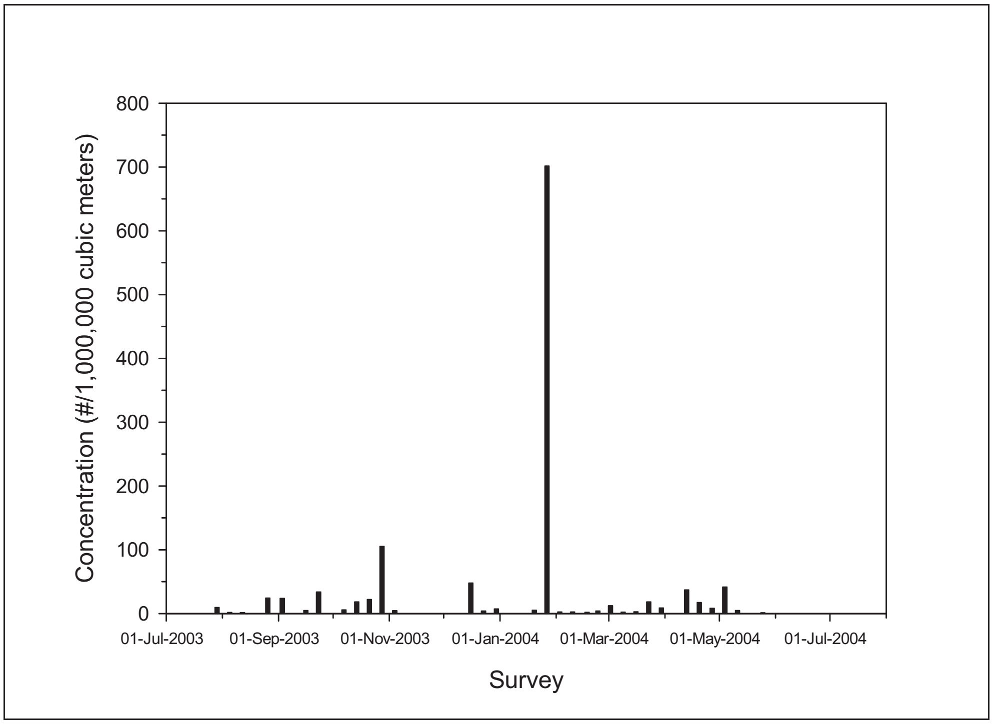

Figure 5-1. Abundance (#/1,000,000 m^3) of fishes collected in HBGS impingement samples from July 29, 2003 through July 20, 2004.

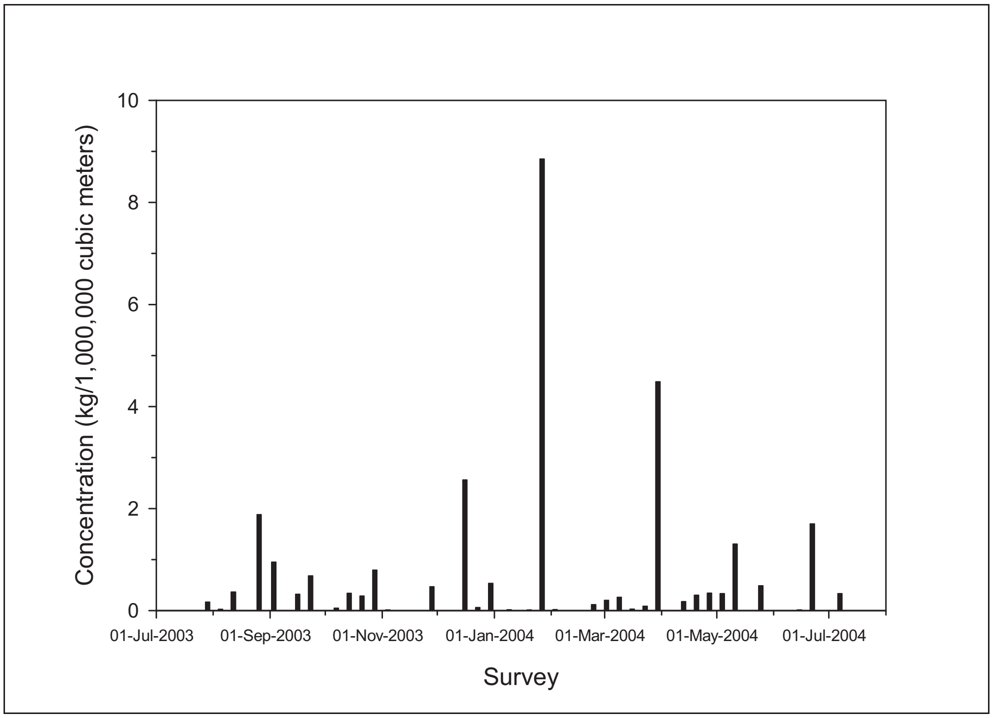

Figure 5-2. Biomass (kg/1,000,000 m^3) of fishes collected in HBGS impingement samples from July 29, 2003 through July 20, 2004.

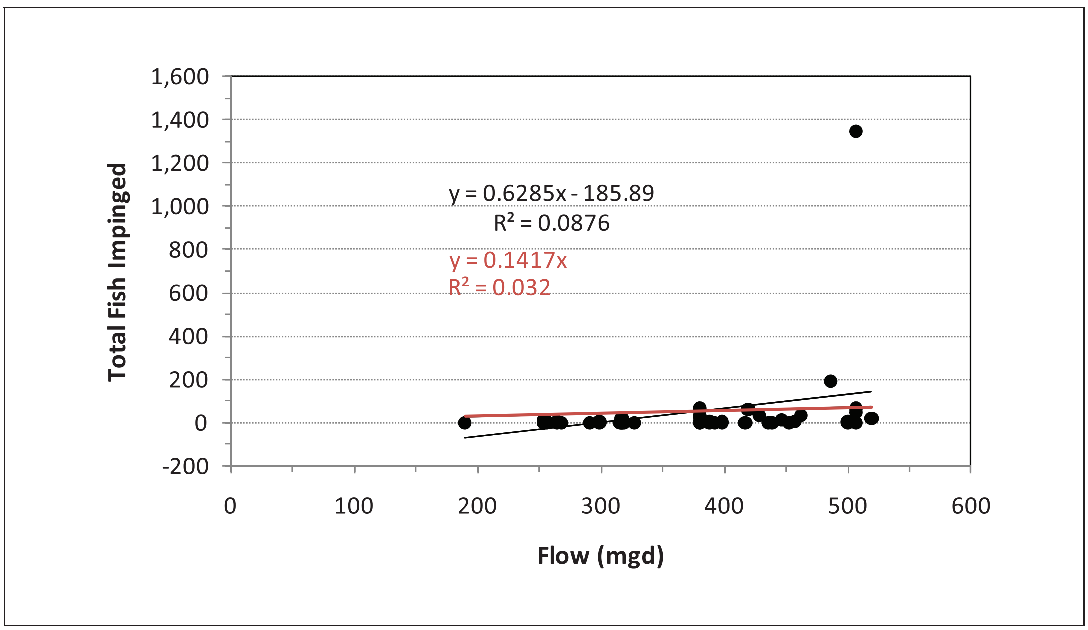

Figure 5-3. Plot of number of fishes (all species) impinged vs. flow rate for HBGS impingement surveys from July 29, 2003 through July 20, 2004. Also shown are regression lines, equations, and R^2 values for non-zero (black) and zero (red) intercept models.

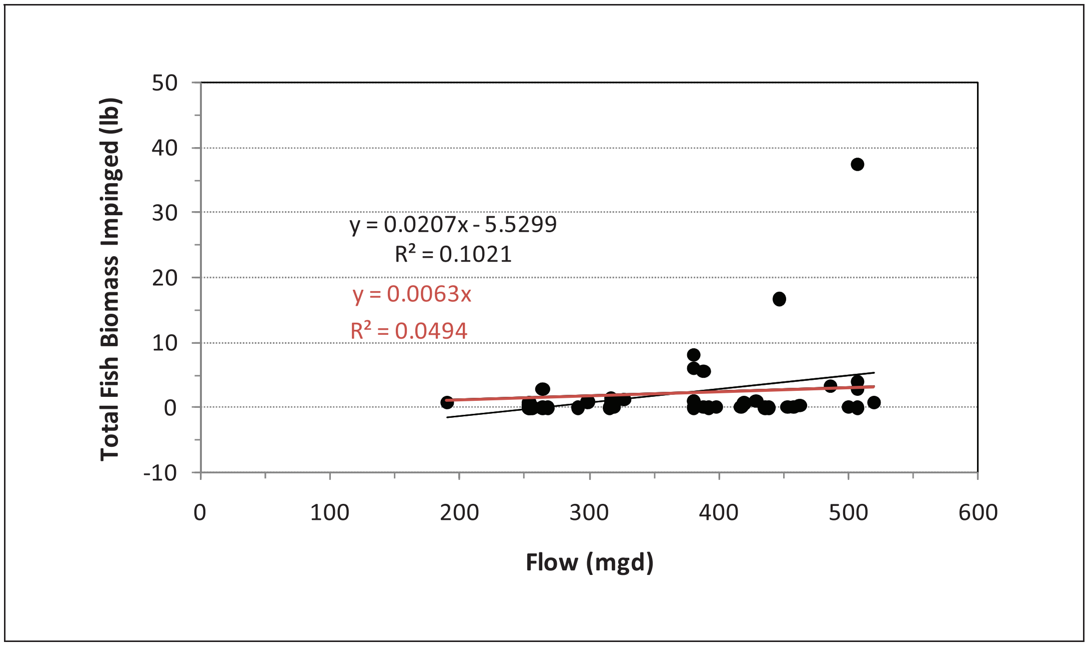

Figure 5-4. Plot of total fishes (all species) biomass impinged vs. flow rate for HBGS impingement surveys from July 29, 2003 through July 20, 2004. Also shown are regression lines, equations, and R^2 values for non-zero (black) and zero (red) intercept models.

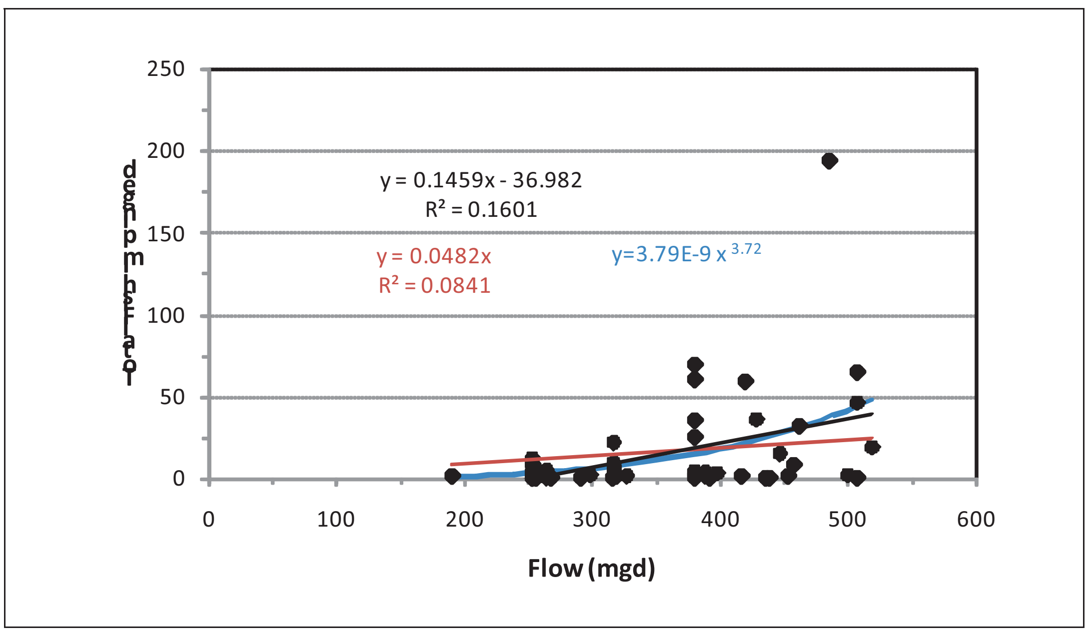

Figure 5-5. Plot of number of fishes (all species) impinged vs. flow rate for HBGS impingement surveys from July 29, 2003 through July 20, 2004, excluding data from January 27, 2004 survey. Also shown are regression lines, equations, and R^2 values for non-zero (black) and zero (red) intercept models. A nonlinear model is shown in blue.

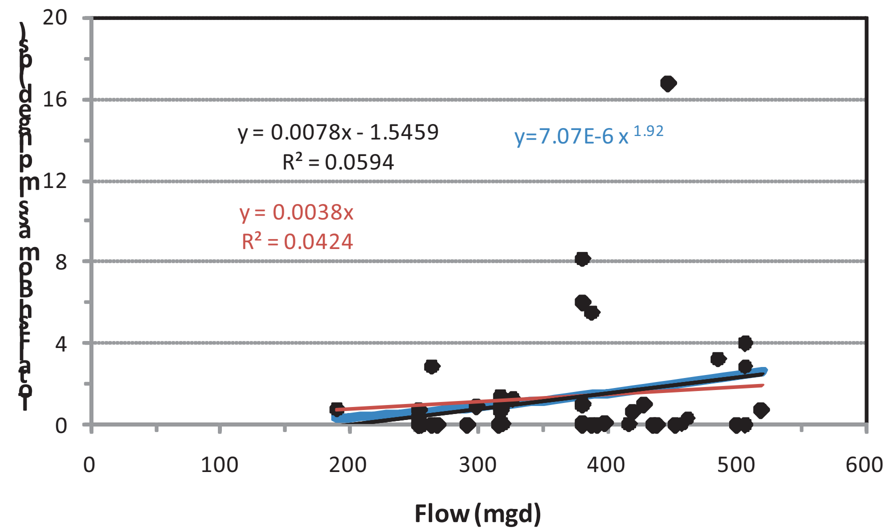

Figure 5-6. Plot of total fishes (all species) biomass impinged vs. flow rate for HBGS impingement surveys from July 29, 2003 through July 20, 2004, excluding data from January 27, 2004 survey. Also shown are regression lines, equations, and R^2 values for non-zero (black) and zero (red) intercept models. A nonlinear model is shown in blue.

Table 5-3. Annual impingement estimates for total number of fishes based on actual flows during 2003–2004 study, 152 mgd flow for HBDF, and extrapolated to 152 mgd daily flow based on regressions of impingement and flow for all surveys, and without the data from January 27, 2004.

Estimation Method	Estimated Abundance	Estimated Biomass (kg)	Estimated Biomass (lb)
Rate extrapolated using actual flows within survey periods	12,692	289.8	638.8
Rate extrapolated using 152 mgd HBDF daily flow within survey periods – weighted average	4,853	117.6	259.2
Rate extrapolated using 152 mgd HBDF daily flow within survey periods – unweighted average based on average flow 359.8 mgd	5,363	122.4	269.9
Rate calculated from zero-intercept model regression of impingement and flow from all surveys, and extrapolated for entire year using 152 mgd HBDF daily flow	7,862	158.5	349.5
Rate calculated from zero intercept model regression of impingement and flow from all surveys except January 27, 2004, and extrapolated for entire year using 152 mgd HBDF daily flow	2,674	95.6	210.8

5.3.2 Shellfish

Annual shellfish impingement during normal operations was estimated at 6,722 individuals from 18 species weighing 76.2 kg (168.1 lb) (**Table 5-4**). The estimated annual total at the proposed HBDF flow of 152 mgd is 2,719 shellfish weighing 38.7 kg (85.4 lb) (**Table 5-5**). Various species of crabs were the most abundant shellfish in impingement samples, while octopus (*Octopus bimaculatus/bimaculoides*), California spiny lobster (*Panulirus interruptus)*, and yellow crab (*Metacarcinus anthonyi*) had the highest biomass.

Table 5-4. Estimated annual shellfish impingement abundance and biomass for normal operations at HBGS based on impingement data collected in 2003–2004 and actual cooling water flow rates.

Species	Common Name	Estimated Total Annual Abundance	Estimated Total Annual Biomass (kg)	Percent of Total Abund.	Percent of Total Biomass
Metacarcinus anthonyi	yellow crab	2,706	21.754	40.3	28.5
Metacarcinus gracilis	graceful crab	1,484	2.905	22.1	3.8
Romaleon antennarius	Pacific rock crab	958	8.588	14.3	11.3
Pyromaia tuberculata	tuberculate pear crab	597	0.955	8.9	1.3
Cancer productus	red rock crab	417	6.101	6.2	8.0
Crangon nigromaculata	blackspotted bay shrimp	336	0.511	5.0	0.7
Pachygrapsus crassipes	striped shore crab	27	0.088	0.4	0.1
Lysmata californica	red rock shrimp	20	0.026	0.3	<0.1
Portunus xantusii	Xantus swimming crab	47	0.292	0.7	0.4
Heptacarpus palpator	intertidal coastal shrimp	27	0.068	0.4	<0.1
Octopus bimaculatus/bimaculoides	two-spotted octopus	27	22.919	0.4	30.1
Pugettia producta	shield-backed kelp crab	26	0.114	0.4	0.1
Panulirus interruptus	California spiny lobster	12	10.998	0.2	14.4
Neotrypaea californiensis	bay ghost shrimp	13	0.060	0.2	0.1
Doryteuthis opalescens	market squid	7	0.442	0.1	0.6
Loxorhynchus crispatus	masking crab	7	0.212	0.1	0.3
Hemigrapsus oregonensis	yellow shore crab	6	0.006	<0.1	<0.1
Farfantepenaeus californiensis	yellowleg shrimp	5	0.185	<0.1	0.2
	Total	**6,722**	**76.224**		
	Number of Species	**18**			

Table 5-5. Estimated shellfish impingement abundance and biomass per year for normal operations, adjusted proportionally for maximum desalination flow (152 mgd).

Species	Common Name	Estimated Total Annual Abundance	Estimated Total Annual Biomass (kg)	Percent of Total Abund.	Percent of Total Biomass
Metacarcinus anthonyi	yellow crab	1,110	7.098	40.8	18.3
Metacarcinus gracilis	graceful crab	522	0.964	19.2	2.5
Romaleon antennarius	Pacific rock crab	346	3.462	12.7	8.9
Pyromaia tuberculata	tuberculate pear crab	264	0.499	9.7	1.3
Crangon nigromaculata	blackspotted bay shrimp	136	1.891	5.9	0.6
Cancer productus	red rock crab	160	0.247	5.0	4.9
Pachygrapsus crassipes	striped shore crab	45	0.098	1.7	0.3
Octopus bimaculatus/bimaculoides	two-spot octopus	36	10.391	1.3	26.8
Panulirus interruptus	California spiny lobster	25	13.555	0.9	35.0
Portunus xantusii	Xantus swimming crab	24	0.146	0.9	0.4
Heptacarpus palpator	intertidal coastal shrimp	14	0.026	0.5	<0.1
Lysmata californica	red rock shrimp	14	0.032	0.5	<0.1
Pugettia producta	northern kelp crab	11	0.038	0.4	<0.1
Neotrypaea californiensis	bay ghost shrimp	4	0.019	0.2	<0.1
Doryteuthis opalescens	market squid	2	0.112	<0.1	0.3
Farfantepenaeus californiensis	yellowleg shrimp	2	0.076	<0.1	0.2
Hemigrapsus oregonensis	yellow shore crab	2	0.002	<0.1	<0.1
Loxorhynchus crispatus	moss crab	2	0.062	<0.1	0.2
	Total	**2,719**	**38.717**		
	Number of Species	**18**			

5.3.3 Impingement Results by Species

Species-specific analyses are limited to the four species that together comprised nearly 92% of total impingement abundance and nearly 23% of impingement biomass estimated for HBDF (**Table 5-2**): queenfish, northern anchovy, white croaker, and shiner perch. Detailed information on the life history and other aspects of the biology of these species is only included in this section for shiner perch. Information for the other three species is presented in Section 4.0—*Entrainment*. Complete data by survey are presented in **Appendix C**.

5.3.3.1 Queenfish (*Seriphus politus*)

Queenfish was the most abundant species collected during normal operations HBGS impingement sampling (**Table 5-1**) with highest abundances and biomass occurring in late January (**Figures 5-7** and **5-8**). Annual impingement using the projected flows for the HBDF was estimated at 3,939 individuals weighing 22.3 kg (49.1 lb) (**Table 5-2**). Queenfish measured in impingement surveys ranged from 40 to 190 mm SL (1.6 to 7.5 in) (**Figure 5-9**). The length distribution was bimodal with peaks at 60 mm (2.4 in) and 120 mm (4.7 in). Queenfish mature at about 127 mm (5 in), during their first spring or second summer (Love 1996). Maximum reported size is 305 mm (12 in) (Miller and Lea 1972). Therefore, most of the fish impinged were young-of-the-year (YOY) and Age-1 fish. Of the 352 mature fish inspected for determination of sex, 253 (72%) were female, and 99 (28%) were male.

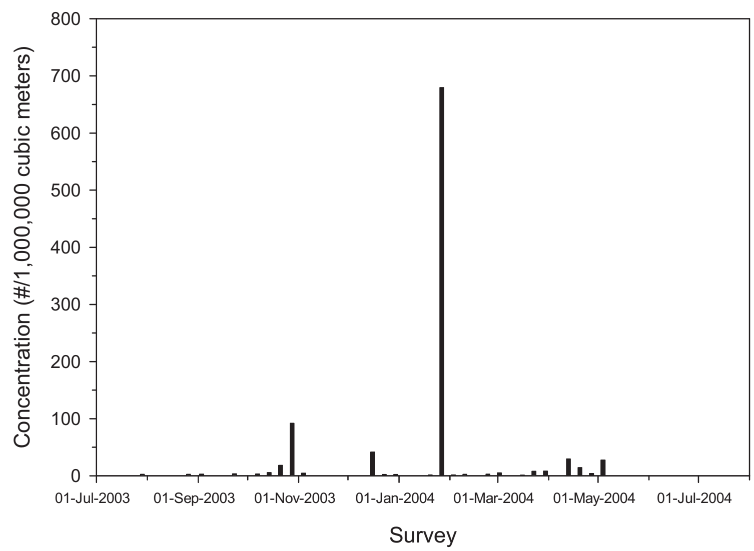

Figure 5-7. Abundance (#/1,000,000 m^3) of queenfish collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

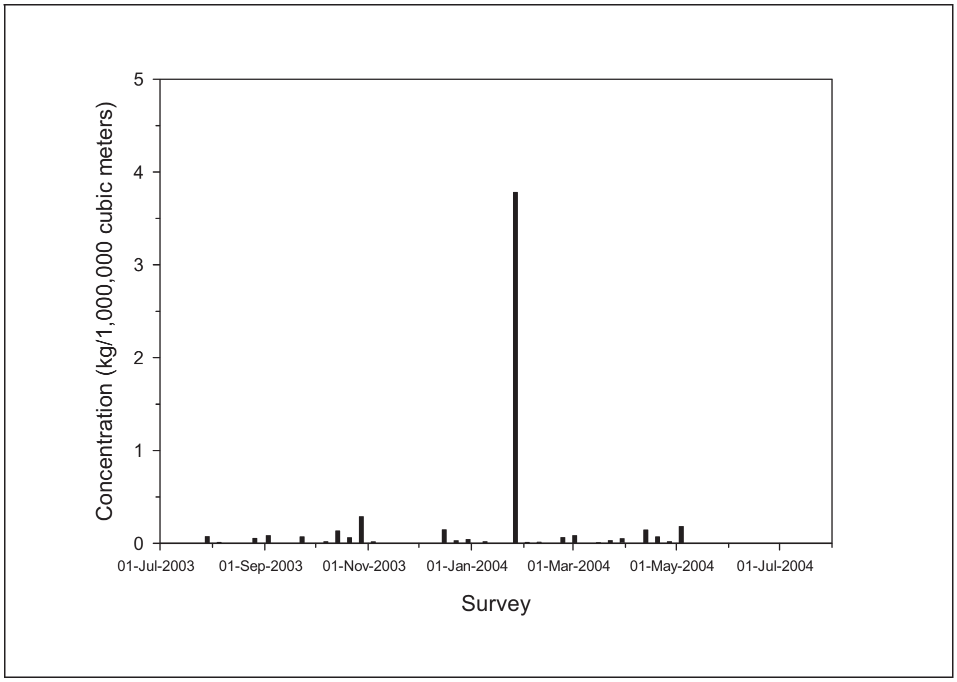

Figure 5-8. Biomass (kg/1,000,000 m^3) of queenfish collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

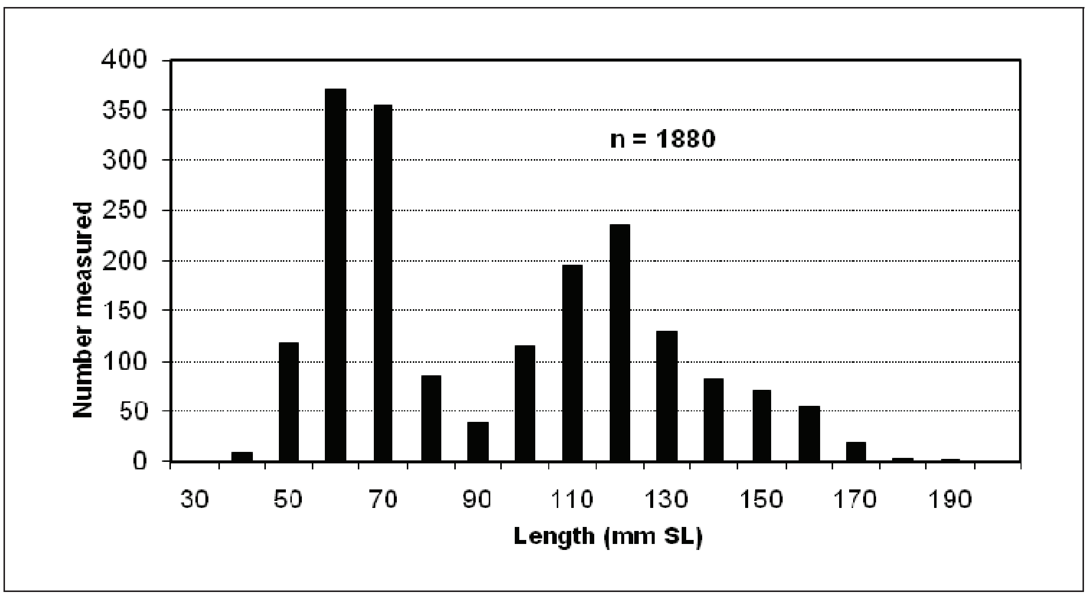

Figure 5-9. Length frequency distribution of queenfish in impingement samples from July 29, 2003–July 20, 2004.

5.3.3.2 Northern Anchovy (*Engraulis mordax*)

Northern anchovy was the second most abundant species in normal operations impingement samples (**Table 5-1**) with highest monthly abundance and biomass occurring in September (**Figures 5-10** and **5-11**). Annual impingement using the projected flows for the HBDF was estimated at 298 individuals weighing 1.9 kg (4.3 lb) (**Table 5-2**). Northern anchovy measured in impingement surveys ranged from 20 to 130 mm SL (0.8 to 5.12 in), with most fish in the 80–90 mm (3.15–3.54 in) size classes (**Figure 5-12**). Northern anchovy reach an average of 102 mm (4 in) in their first year, and 119 mm (4.7 in) in their second year (Sakagawa and Kimura 1976). Therefore, most of the impinged fish were Age-0 and Age-1 fish. Of the 86 mature individuals dissected for determination of sex, 74 (86%) were female and 12 (14%) were male.

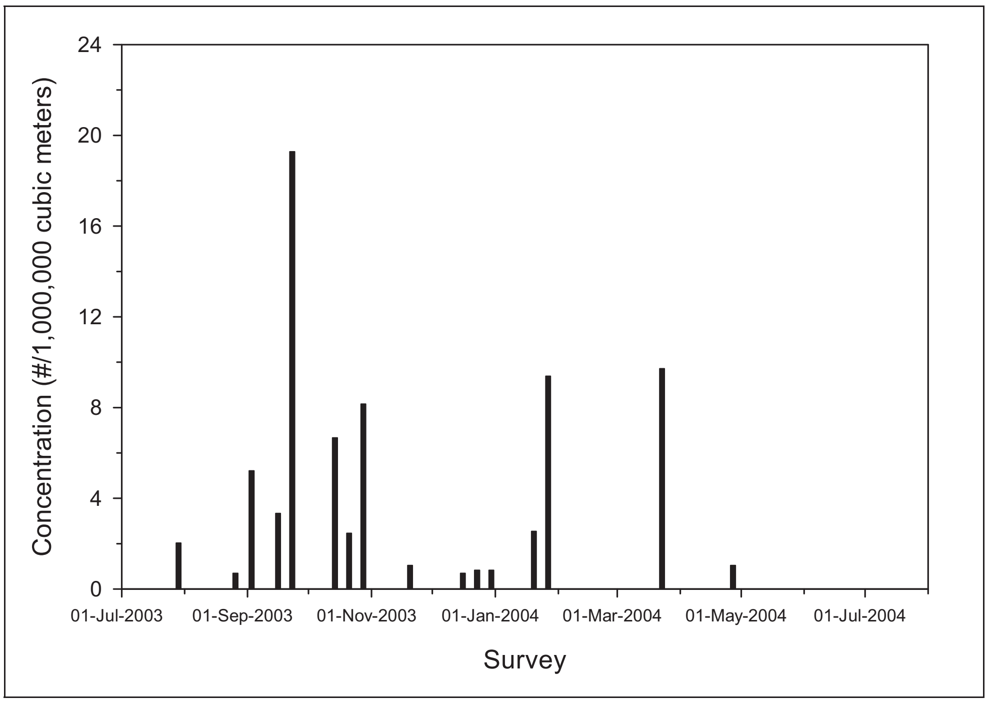

Figure 5-10. Abundance (#/1,000,000 m^3) of northern anchovy collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

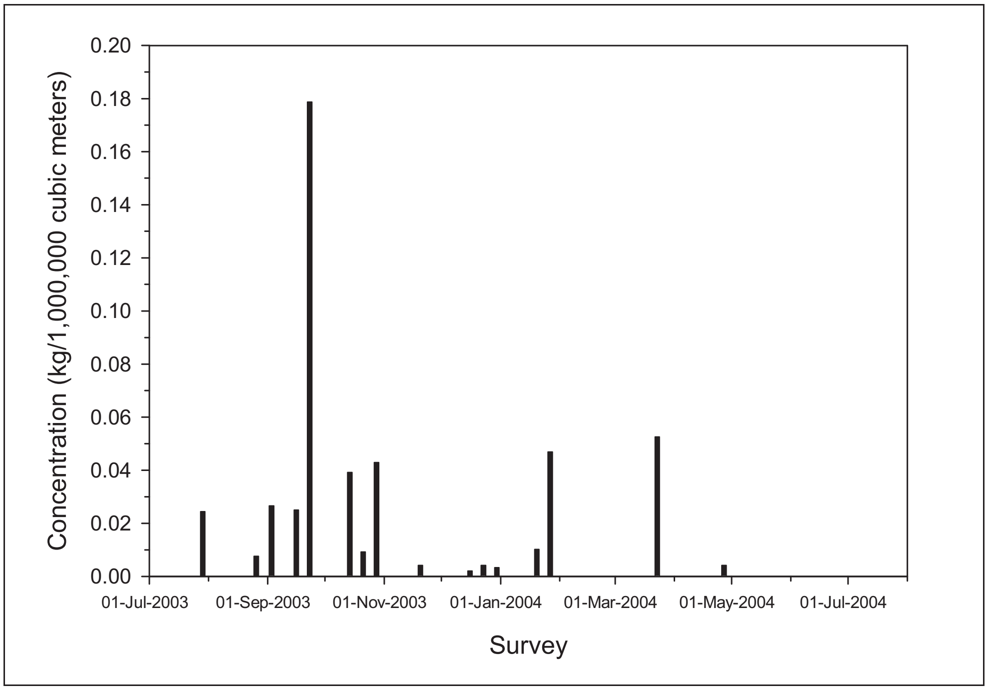

Figure 5-11. Biomass (kg/1,000,000 m^3) of northern anchovy collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

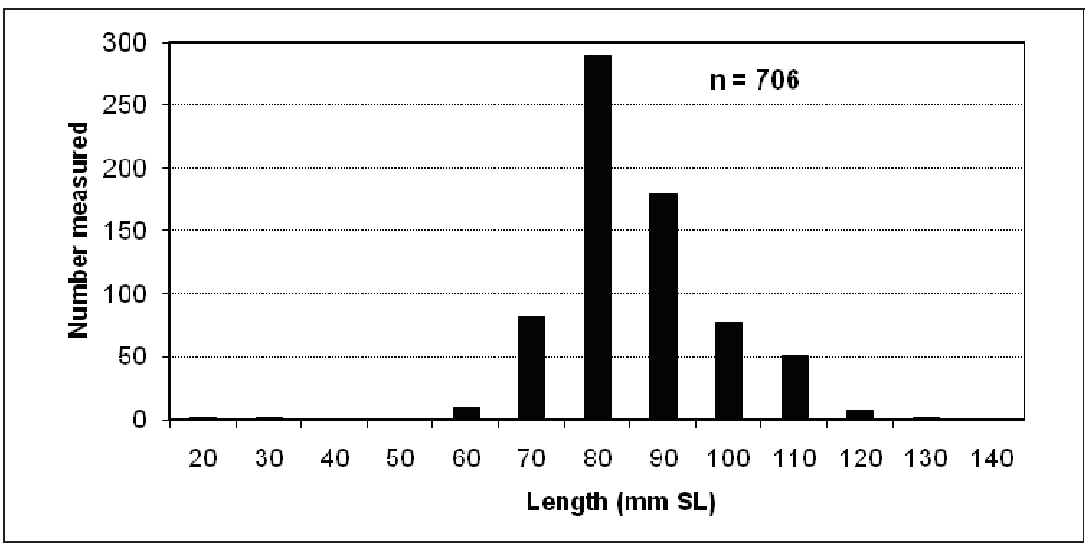

Figure 5-12. Length frequency distribution of northern anchovy collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

5.3.3.3 White Croaker (*Genyonemus lineatus*)

White croaker was the third most abundant species in normal operations impingement samples (**Table 5-1**) with highest abundance and biomass in August 2003 (**Figures 5-13** and **5-14**). Annual impingement using the projected flows for the HBDF was estimated at 127 individuals weighing 1.5 kg (3.3 lb) (**Table 5-2**). The white croaker measured in impingement surveys ranged from 50 to 200 mm SL (1.97 to 7.87 in) in size, with most fish in the 80–90 mm (3.15–3.54 in) size classes (**Figure 5-15**). White croaker mature between about 130 and 190 mm (5.12 and 7.5 in), between their first to fourth year (Love et al. 1984, Love 1996). Therefore, most of the white croaker impinged were probably YOY. Of the 108 mature individuals inspected for determination of sex, 61 (56%) were female and 47 (44%) were male.

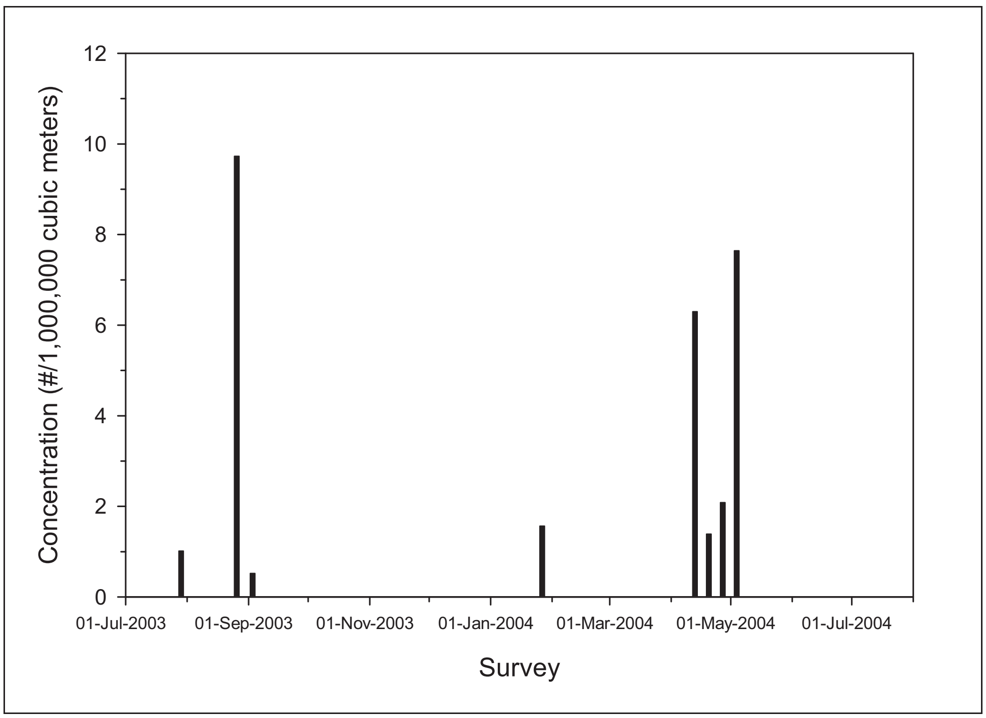

Figure 5-13. Abundance (#/1,000,000 m^3) of white croaker collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

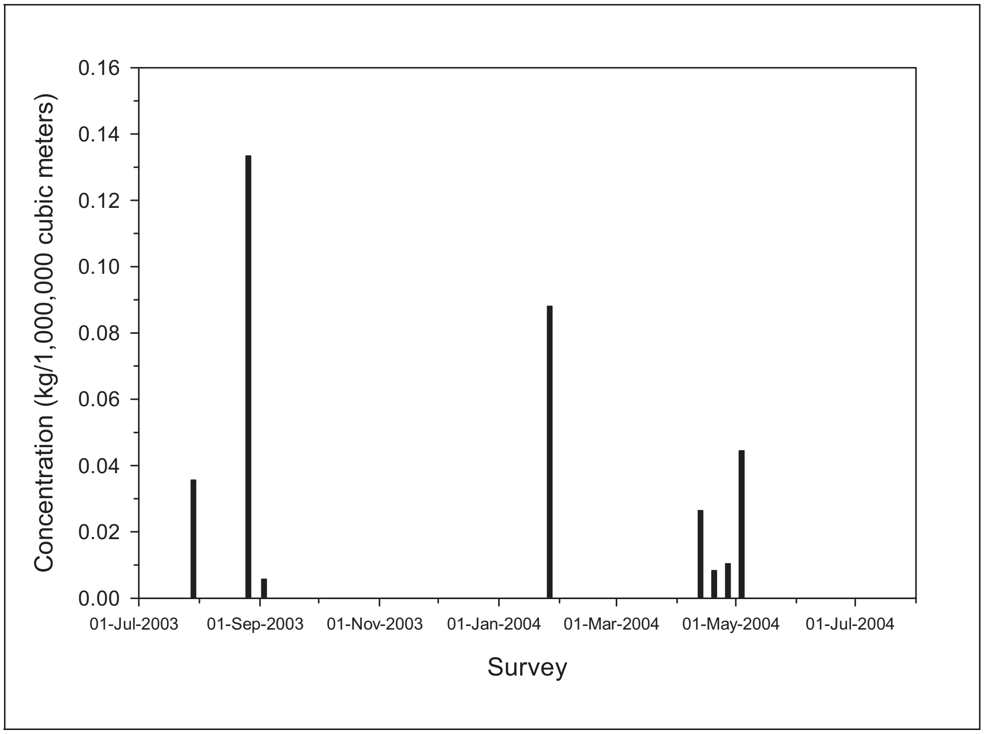

Figure 5-14. Biomass (kg/1,000,000 m^3) of white croaker collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

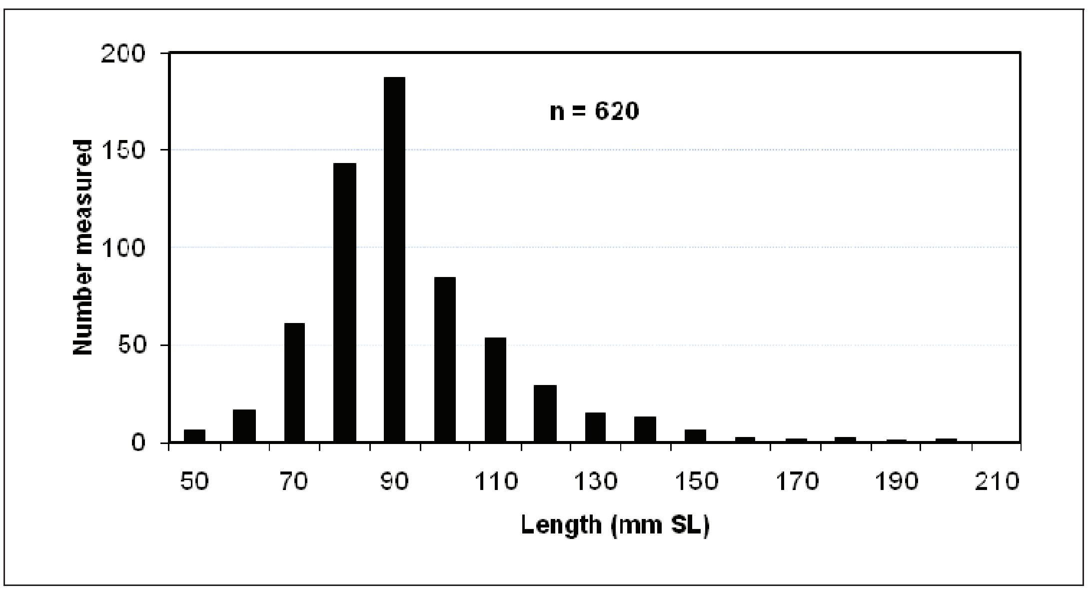

Figure 5-15. Length frequency distribution of white croaker in impingement samples from July 29, 2003–July 20, 2004.

5.3.3.4 Shiner Perch (*Cymatogaster aggregata*)

Shiner perch ranges from San Quintin Bay, Baja California to Port Wrangell, Alaska (Miller and Lea 1972). It occurs primarily in shallow-water marine, bay, and estuarine habitats (Emmett et al. 1991), and is demersal on sandy and muddy bottoms. On the southern California shelf, shiner perch have been reported to occur as deep as 90 m (295.3 ft), but Allen (1982) reported that most occur shallower than about 70 m (229.7 ft). This species forms schools or loose aggregations during the day (Fitch and Lavenberg 1975), but solitary individuals are found on the bottom at night. Shiner perch, along with white croaker, formed Allen's (1982) "nearshore schoolers" recurrent group; the two species occur commonly off southern California even though shiner perch is considered to be mainly a cold-temperate, outer-shelf species, while white croaker is characterized as a temperate, inner-shelf species.

5.3.3.4.1 Reproduction, Age and Growth

Eggs of the shiner perch are fertilized internally, and females give birth to live young. At birth, fully developed young are about 34 to 78 mm (1.3 to 3.1 in) in length (Wilson and Millemann 1969, Hart 1973). Mating occurs primarily in the spring and summer in California (Bane and Robinson 1970). The reproductive capacity of this species is directly related to female size—smaller females produce as few as five young, while larger females can produce over 20 young (Wilson and Millemann 1969). Shiner perch live for about eight years and reach about 180 mm (7.1 in) in length (Miller and Lea 1972, Hart 1973).

5.3.3.4.2 Population Trends and Fishery

This species is not commercially important, but some shiner perch are landed for bait and human consumption (Emmett et al. 1991). Shiner perch are fished recreationally, especially from piers and in bays and estuaries (Love 1996). Numbers of shiner perch in southern California waters declined after the mid-1970s, and this is likely related to warming ocean temperatures, decreased zooplankton biomass, and reduced upwelling (Stull and Tang 1996, Beck and Herbinson 2003, Allen et al. 2003). Annual recreational landings in southern California from 2004–2008 averaged approximately 50,000 fish with a high of 128,000 in 2004 (RecFIN 2009; **Table 5-6**).

Table 5-6. Annual recreational fishing catch estimates for shiner perch in the southern California region (RecFIN 2009).

Year	Estimated Catch	Estimated Weight (MT)	Estimated Weight (lb)
2004	128,000	4	8,818
2005	46,000	1	2,205
2006	11,000	0	720*
2007	22,000	1	2,205
2008	40,000	1	2,205
average	**49,400**		

* not listed in RecFIN database; calculated based on average weight per fish for other years combined.

5.3.3.4.3 Sampling Results

Shiner perch ranked fourth in normal operations impingement abundance (**Table 5-1**) with highest abundances and biomass recorded in September 2003 (**Figures 5-16** and **5-17**). Annual impingement using the projected flows for the HBDF was estimated at 85 individuals weighing 0.8 kg (1.8 lb) (**Table 5-2**). Shiner perch measured in impingement surveys ranged from the 40 to 120 mm SL (1.6 to 4.7 in) in size, with most fish in the 70 mm (2.8 in) size class (**Figure 5-18**). Therefore, most of the impinged fish were juveniles. The smallest shiner perch (40 and 50 mm [1.6 and 1.97 in.] size classes) appeared in May 2004, corresponding to the known spawning season of shiner perch (Bane and Robinson 1970). Of the 170 mature fish inspected for determination of sex, 130 (76%) were female, and 40 (24%) were male.

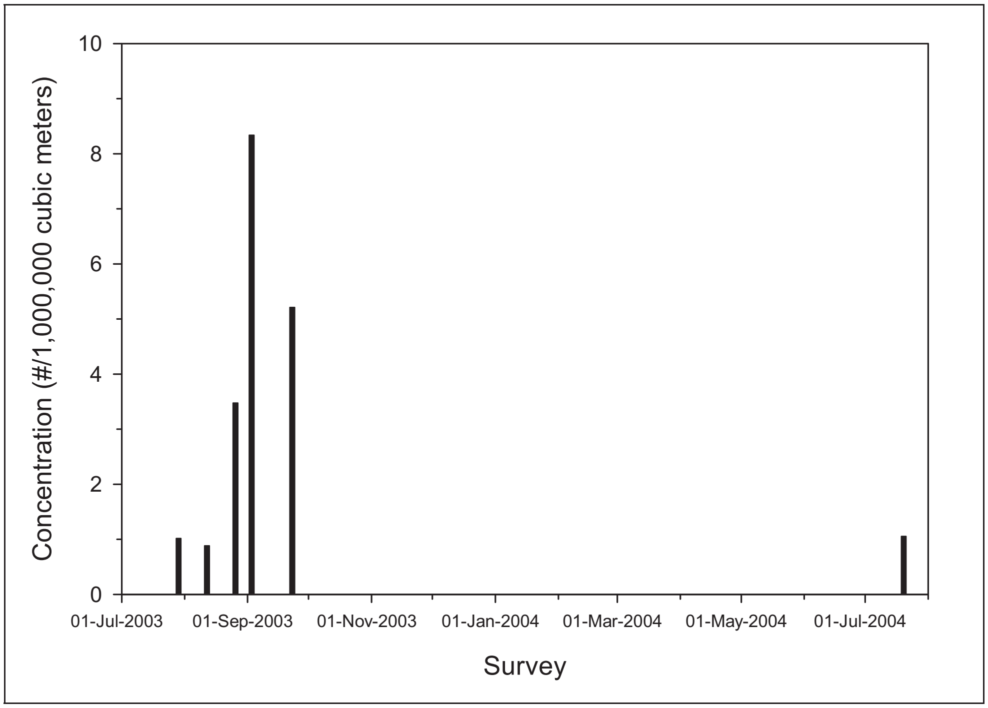

Figure 5-16. Abundance (#/1,000,000 m^3) of shiner perch collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

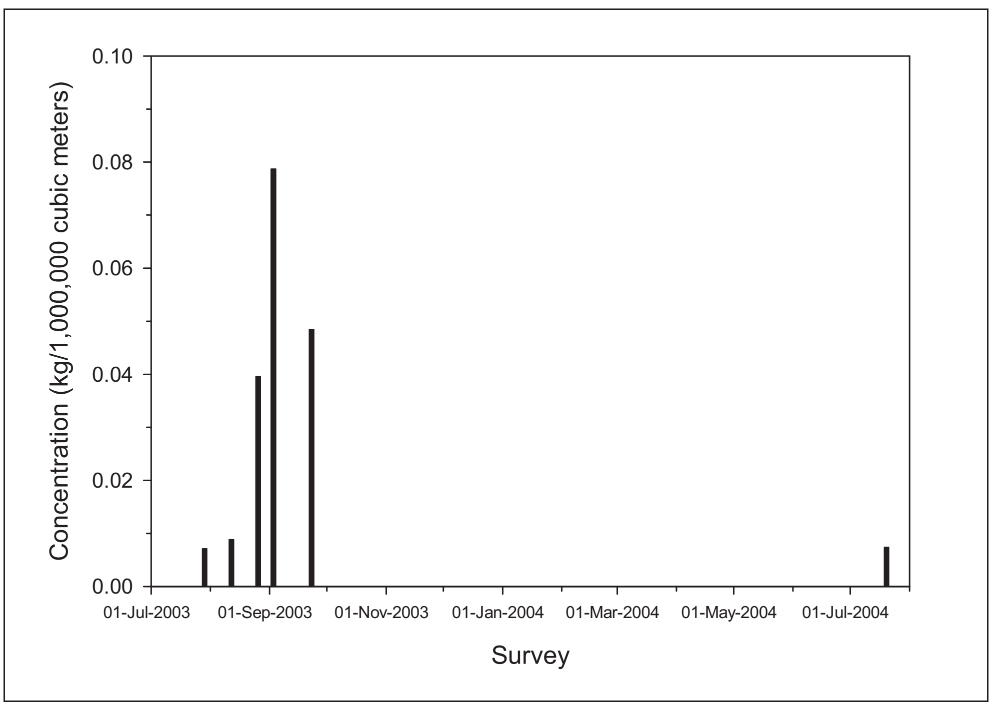

Figure 5-17. Biomass (kg/1,000,000 m^3) of shiner perch collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

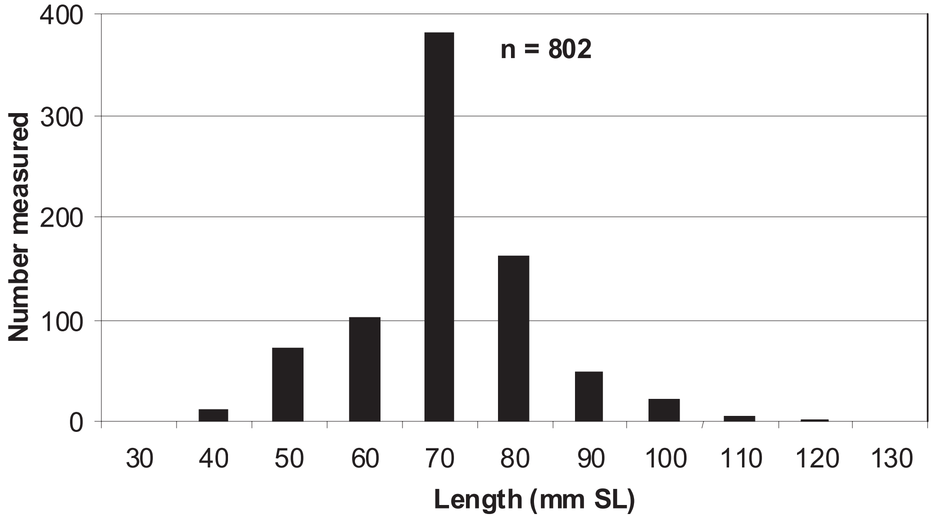

Figure 5-18. Length frequency distribution of shiner perch collected in HBGS impingement samples from July 29, 2003–July 20, 2004.

6.0 Impact Assessment

6.1 Impact Assessment Overview

The purpose of the original impingement and entrainment (I&E) study done in 2003 and 2004 was to assess the effects of the operation of the AES Southland Huntington Beach Generating Station (HBGS) cooling water intake system on populations of marine fishes and invertebrates from. A re-analysis of the data from that study presented in this report examines the potential effects due to the operation of the intake solely for the purposes of providing seawater for the proposed Huntington Beach Desalination Facility (HBDF). The maximum intake flow for HBGS is 507 mgd (1.92 x 10^6 m^3). The analyses in the original I&E study used the maximum and actual cooling water flows in the analyses. The same analysis approach was used in this report but with the results scaled to the lower projected intake volume for the HBDF of 152 mgd (0.575 x 10^6 m^3). The analyses presented in this report use the same data collected during the original one-year entrainment study (September 2003–August 2004) and one-year impingement study (July 2003–July 2004). Entrainment was measured by collecting plankton samples near the HBGS intake structure and estimating the numbers of larvae potentially entrained based on cooling water flows. Impingement was estimated by direct counts of fishes and macroinvertebrates impinged at the HBGS during normal operations and heat treatment surveys, although only normal operations impingement data were considered in the present report because heat treatment operations would be unnecessary for operation of the HBDF.

The analysis of effects due to operation of the HBDF intake was limited to the most abundant fishes and a list of target invertebrates collected during the course of the study. The most abundant organisms may have higher risk for population-level impacts, but their high levels in I&E samples also probably reflects their high overall abundance in the source water. Therefore all of the estimates need to be placed in context, either through the estimates of the source water areas affected or through independent estimates of the adult populations. The entrainment estimates were based on the conservative assumption that none of the entrained organisms survive passage through the circulating water system. While this has been the operating assumption for power plant CWIS studies due to the high probability of mortality from the thermal and pressure changes as they pass through the system, the chance of survival is much higher for desalination facility intakes where a large portion of the water is only used for dilution of the concentrated seawater discharge.

The life history of species in the community must be considered when discussing potential effect to fish and shellfish populations due to operation of the CWIS at the HBGS. Although the study focused on species potentially affected by I&E, it is important to note that several fishes have life stages that are not susceptible to I&E. For example, live-bearers, such as surfperches, some sharks, and some rays, produce young that are fully developed and too large to be affected by entrainment. From the standpoint of impingement effects, most gobies would not be subject to impingement because they are bottom-dwelling species that typically do not move up into the water column. Even fishes that swim in the water column are generally not susceptible to impingement effects as they mature because they are able to swim against the slow approach velocity of the cooling water inflow.

The larval fishes collected for entrainment at the intake station differed somewhat from the juvenile and adult fishes that were impinged. The most abundant fish larvae in entrainment samples (CIQ gobies) comprised 32.8% of HBDF estimated annual entrainment, but because their primary habitat is bays and estuaries, none was collected in impingement samples. The same was true for combtooth blennies, which were the eight most abundant larval fish based on HBDF estimated total annual entrainment. Combtooth blenny adults typically inhabit rocky and fouling habitat in embayments and shallow nearshore areas, little of which occurs in the immediate vicinity which do not occur in the vicinity of the HBGS intake. Two of the other abundant larval fish species, white croaker and northern anchovy, were well represented in impingement samples. Conversely, the most abundant fish species collected in impingement samples (queenfish) was not as abundant in the entrainment samples, comprising approximately 5% of estimated annual entrainment.

6.2 Summary of Entrainment Results

Entrainment impacts were assessed, when sufficient information was available, using two demographic models, Adult Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*), which translate larval entrainment estimates into adult losses. A third modeling approach, the Empirical Transport Model (*ETM*), compared the numbers of larvae entrained with the numbers of larvae at risk of entrainment in the source waters to obtain an estimate of the proportional mortality caused by entrainment. The pool of larvae within the source waters that are at risk of entrainment is very large in comparison with the numbers that are actually entrained. For example, an estimated 34,000,000 goby larvae would be entrained annually, based on the 2003–2004 data, but the potential pool of goby larvae at risk in the source water was estimated to be over 15,000,000,000. Results from the modeling estimates are presented in **Table 6-1**.

The data collected during the HBGS 2003–2004 study were used to estimate that a total of approximately 103 million larval fishes would be entrained annually by the HBDF if operated at full capacity (152 mgd), an average of about 282,200 larvae per day. The study results showed that the CIQ goby complex was the most abundant larval fish taxon in both the entrainment and source water samples, comprising 32.8% of total estimated annual entrainment (**Table 4-2**). The CIQ goby complex is comprised of up to three species that are common in southern California bays and estuaries (arrow, shadow, and/or cheekspot gobies) and, as early larvae, cannot be reliably identified to the species level. Spotfin croaker was the second most abundant fish taxon comprising 20% of total estimated annual entrainment mainly due to very high concentrations of spotfin during a single survey in August 2004. Northern anchovy was the third most abundant fish taxon comprising nearly 16% of total estimated annual entrainment and the second most abundant in the source water based on annual mean concentration. In addition to spotfin croaker, three additional species of croakers were also included in the assessment. White croaker larvae were relatively abundant throughout the sampling period, while queenfish and black croaker were not abundant until the latter part of the study in July and August 2004.

Table 6-1. Summary of entrainment modeling estimates on target taxa based on the three modeling techniques (*FH, AEL,* and *ETM* [P_M]). The *FH* model estimates breeding adult females, therefore this estimate is multiplied by two for comparison with the *AEL* model that estimates numbers of adults, irrespective of sex. The comparison assumes a 50:50 ratio of males:females in the population. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate. The population at risk was estimated by dividing the alongshore extrapolation of P_M by the estimated larval entrainment.

Taxon	Estimated Annual Larval Entrainment	Estimated Annual Source Water Population at Risk	2·*FH*	*AEL*	P_M Alongshore Extrapolation	P_M Offshore Extrapolation
CIQ goby complex	33,927,750	15,749,000,000	85,418	*	0.21% (76.7 km)	**
spotfin croaker	20,896,741	58,199,000,000	*	*	0.04% (33.9 km)	0.04%
northern anchovy	16,293,995	6,807,000,000	52,472	365,837	0.24% (94.8 km)	0.12%
queenfish	5,339,449	7,435,000,000	14	*	0.08% (91.5 km)	0.05%
white croaker	5,284,106	5,519,000,000	36	*	0.10 % (75.4 km)	0.04%
salema	3,506,783	–	*	*	–	–
combtooth blennies	2,148,242	2,992,000,000	2,450	*	0.07% (18.3 km)	**
black croaker	2,137,034	8,928,000,000	*	*	0.02% (55.1 km)	0.02%
diamond turbot	1,631,863	1,948,000,000	*	*	0.08% (49.4 km)	0.06%
California halibut	1,505,361	6,289,000,000	4	*	0.03% (76.2 km)	<0.01%
rock crab megalops	2,324,020	693,000,000	*	*	0.33% (100.3 km)	0.22%
Total	94,995,344	114,559,000,000				

* No estimate due to either insufficient life history information or low abundance in entrainment samples.

** No extrapolation to offshore areas because the taxon has an exclusively alongshore distribution.

– *ETM* values could not be calculated because there were no surveys during which salema larvae were present in both entrainment and source water samples.

The fish taxa that were the focus of the analysis in this report each have different distributions and life histories. They include fishes that are primarily distributed in estuarine and enclosed bay habitats, in coastal nearshore habitats, and in coastal open ocean habitats. The CIQ goby adults are generally not found along the open coast where the HBGS intake structure is located—only 25 gobies have been impinged at the HBGS since 1979 (3 cheekspot and 22 arrow gobies), and none have been collected in annual trawls off the HBGS since 1976. Although adult gobies are relatively small, bottom-dwelling fishes and may not have been adequately sampled by the mesh of the traveling screen or otter trawls, the coastal habitat off the generating station is not well suited for any of these three species of gobies, and it is unlikely there are large numbers of adult gobies off the coast of Huntington Beach. More likely, the adult populations are concentrated in nearby coastal embayments and harbors, such as Alamitos Bay, Anaheim Bay, and Talbert

Marsh, and their larvae are dispersed in these environs and transported out into coastal waters by tidal flushing and prevailing currents. The arrow goby is an abundant constituent of the fish community at the Golden Shore Marine Reserve, a created wetland at the mouth of the Los Angeles River approximately 22 km (13 mi) upcoast from the HBGS (MBC 2003b). During the final year of a five-year mitigation monitoring project, densities of arrow goby ranged from 0.7 individuals/m^2 in winter to 4.5 individuals/m^2 in summer, but may have been even higher due to some escapement through the 6-mm seine mesh used for sampling. MacDonald (1975) found densities of 4 to 5 individuals/m^2 in Anaheim Bay in winter, although concentrations of up to 20 individuals/m^2 were found in some individual burrows. Combtooth blennies and diamond turbot are two other taxa that are primarily distributed in estuarine and bay habitats (Love 1996).

The *ETM* results showed that the additional mortality to the source population resulting from entrainment from HBDF operations was very low for gobies, blennies and diamond turbot. The estimates of the additional mortality due to entrainment (P_M) were 0.21% or less for all three taxa (**Table 6-1**). Demographic modeling (*FH*) of CIQ gobies larval entrainment estimates showed potential losses of approximately 85,500 adults. The *ETM* and demographic modeling results overestimate the effects of entrainment on the adult populations of these taxa, which are primarily distributed in bay and estuarine areas. Adult populations of these fishes, CIQ gobies in particular, are generally restricted to estuarine areas and the larvae of gobies have been observed to have swimming behavior that reduces their transport into coastal waters by tidal currents (Barlow 1963, Pearcy and Myers 1974, Brothers 1975). Although the larvae that are transported into coastal waters provide for genetic exchange between estuarine areas along the coast (Dawson et al. 2002), they also experience much higher rates of mortality than larvae that are retained in estuarine areas. As a result, the survival rates from an estuarine area (Brothers 1975) used in the *FH* model for CIQ gobies was probably much lower than the actual survival in the open coastal waters resulting in overestimates of the actual effects at the adult population level. Similarly, the magnitude of any effects at the adult population level would be much less than even the low estimates of P_M, because this is an estimate of the mortality on the larval population in open coastal waters and would not apply to larvae retained in estuarine areas that actually would be contributing to adult recruitment.

Entrainment effects due to operation of the HBDF on fishes primarily distributed along outer coastal habitats, including California halibut, queenfish, white croaker, spotfin croaker, and black croaker were also low, with the estimated additional mortality due to HBDF entrainment of approximately 0.1% or less (**Table 6-1**). Estimated effects from the *ETM* were even less when the potential source population was increased to include offshore areas. Another open coastal species, salema, was not assessed using any of the models because it was only present during two surveys at the source water and entrainment stations, but not during the same surveys. Therefore, we were unable to calculate estimates of *PE* for salema that were necessary to complete the *ETM* calculations. In addition, there is very little life history information available for salema necessary for demographic modeling.

Northern anchovy is a pelagic species that is known to occur at least 480 km (298.3 mi) from shore, and is one of the most abundant fish species off the southern California coast. Juvenile northern anchovy, which were collected in HBGS impingement samples, are usually found closer to shore, including in embayments and estuaries. Northern anchovy is the numerically dominant fish collected in annual trawl surveys off the HBGS, and ranks third in historical impingement abundance. Live-bait boats commonly fish the nearshore areas between the HBGS and Newport Harbor for this species. The estimated entrainment mortality based on both offshore and alongshore extrapolation of the source population is probably the most appropriate estimate to use for this wide-ranging species and this estimate from *ETM* indicates that the additional mortality resulting from entrainment is approximately 0.2% over a coastal distance of 95 km (59 miles) (**Table 6-1**). Although the two demographic model estimates for northern anchovy provide a wide range of estimates, the estimated numbers of adults lost due to entrainment (ranging from *2FH*=52,472 to *AEL*=365,837 or approximately 0.4 to 5.5 metric tons [MT] using 14.9 g. [0.5 oz] as the biomass of an Age-1 fish) are low given the large adult populations of northern anchovy in the Southern California Bight. These adult losses can be compared to stock estimates of 388,000 metric tons (430,000 tons) of northern anchovy in the region from San Francisco to Punta Baja, Mexico (Jacobson et al. 1997).

Rock crabs (family Cancridae) were the only larval target invertebrate taxa collected in sufficient abundance for analysis. Although large numbers of sand crab larvae were collected, only two of the larvae were in the later megalops stage chosen as target organisms for assessment. The other invertebrate target taxa were not collected in any of the entrainment samples. Similar to the results for the fishes, the estimated increased mortality due to entrainment for rock crab megalops larvae was low, 0.2 to 0.3% (**Table 6-1**). The P_M estimates for rock crabs were higher than the fishes analyzed because the larval duration used in the modeling was much longer than the durations used for the fishes. Although the larval duration for the megalops stage we analyzed is only 12 days (Anderson and Ford 1976) we used a larval duration of 45 days in the model to account for the earlier larval stages not sampled. This approach assumes that the *PE* estimated for the megalops is representative of the earlier larval stages.

Several of the species analyzed in this report are commercial species with landings data that allow the direct value of the entrainment losses to be calculated. These calculations include several assumptions that make the estimates extremely conservative. Most importantly, the use of larval losses implies that these translate directly to equivalent losses to the adult populations. This assumption ignores all the voluminous literature on population regulation (Christensen et al. 1977, Saila et al. 1987, Barnthouse and Van Winkle 1988, Newbold and Iovanna 2007) that would indicate that compensation for larval and juvenile losses, especially very early stage larvae, does not necessarily result in equivalent losses to the adult population. Also, the fishery data used in the calculations is for fishes landed at ports in Los Angeles County and therefore may cover a much larger area than the areas used to define the source populations in the *ETM* modeling. Even though the offshore extrapolated source water estimates of P_M were used in the calculations, the value of the catch probably exceeds the value of the catch in the extrapolated source population by a significant amount.

Catch data from Los Angeles ports for 2004–2008 were used to estimate the value of entrainment losses for northern anchovy, white croaker, California halibut, and rock crabs. The average annual revenue for northern anchovy landed in the Los Angeles region for the period from 2004–2008 was $115,169 (**Table 4-12**). Since these northern anchovy fishery landings include fish from offshore areas, the P_M estimate based on offshore extrapolation of 0.0012 (**Table 4-18**) was used to estimate that the northern anchovy entrainment losses translate to a value of $136 annually. This valuation is almost three times that estimated from fecundity hindcasting ($48) but one-fifth of an *AEL*-based estimate ($667). The average annual revenue for white croaker landed in the Los Angeles region for the period from 2004–2008 was $9,873 (**Table 4-23**). Since these white croaker fishery landings include fish from offshore areas, the P_M estimate based on offshore extrapolation of 0.00044 (**Table 4-26**) was used to estimate that the white croaker entrainment losses translate to a value of only $4 annually. The average annual revenue for California halibut landed in the Los Angeles region for the period from 2004–2008 was $318,772 (**Table 4-34**). Since these landings include California halibut from offshore areas, the P_M estimate based on offshore extrapolation of 0.00004 (**Table 4-37**) was used to estimate that the California halibut entrainment losses translate to a value of $13 annually. The average annual revenue for rock crab landed in the Los Angeles region for the period from 2004–2008 was $155,235 (**Table 4-38**). Since these rock crab landings include crabs caught over a broad area including offshore, the P_M estimate based on offshore extrapolation of 0.00217 (**Table 4-40**) was used to estimate that the rock crab entrainment losses translate to a value of $336 annually. Total annual estimated entrainment value for northern anchovy, white croaker, California halibut, and rock crabs entrained is $489.

One of the summary conclusions in the original report on the I&E studies at HBGS were that estimated levels of P_M were much less than the estimates from other coastal power plants in California. This was attributed to the location of the plant along a fairly homogeneous stretch of coastline dominated by sandy habitat that provides much less habitat for fishes than rocky coastal or estuarine areas where some of the other plants are located. The location of the HBGS intake affects the results in several important ways. First of all, several of the plants are located in estuarine areas that have very limited source water bodies relative to the open coastal source water for the HBGS intake. The decreased source water bodies for these studies result in higher P_M estimates relative to the HBGS. The coastal currents in the vicinity of the HBGS spread any effects of the entrainment losses over tens of kilometers of coastline limiting any effects to the populations. Also the habitat in the vicinity of the HBGS intake is relatively homogeneous sand flats that extend for several kilometers north, south and offshore of the intake. This homogeneous environment probably results in a more uniform distribution of larvae throughout the sampling area resulting in average estimates of *PE* that closely approximated the volumetric ratio of the projected HBDF daily flow to the sampled source water volume of 0.00063 for cancer crabs and several of the more abundant fishes. As a result, the P_M estimates were more dependent on the estimated larval durations and currents used to calculate the source water body. This result helps support the approach taken in the cumulative impact assessment that relies solely on the volumetric withdrawal of cooling water in estimating proportional entrainment for the model.

The low volume and location of the intake help reduce the potential effects of the operation of the HBDF on coastal fish and shellfish populations.

6.3 Summary of Impingement Results

An estimated average of approximately 13 fishes weighing a total of 0.3 kg (0.7 lb) would be impinged daily based on the operation of the HBGS intake for the proposed HBDF. This is based on an annual impingement estimate of 4,853 fishes weighing 117.6 kg (259 lb) (**Table 5-2**). The totals do not include impingement during heat treatment operations which were included in the totals reported in the original I&E report for HBGS. Of the 36 species impinged, the most abundant based on estimated total annual impingement were queenfish (81%), northern anchovy (6%), white croaker (3%), and shiner perch (2%) (**Table 5-2**). All of the other fishes comprised one percent or less of the total estimated annual impingement. Queenfish, white croaker, and northern anchovy are the overall long-term dominants in annual HBGS impingement sampling since 1979. The fishes comprising the greatest percentages of estimated total annual impingement biomass were Pacific electric ray (41%), queenfish (19%), round stingray (7%), thornback (5%), and specklefin midshipman (5%) (**Table 5-2**).

An estimated average of approximately 7 shellfish individuals weighing a total of 0.1 kg (0.2 lb) would be impinged daily based on the operation of the HBGS intake for the proposed HBDF. This is based on an annual impingement estimate of 2,719 shellfishes weighing 38.7 kg (85.4 lb) (**Table 5-5**). The totals do not include impingement during heat treatment operations, which were included in the totals reported in the original I&E report for HBGS. Of the 18 species impinged, the most abundant based on estimated total annual impingement were yellow crab (41%), graceful crab (19%), and Pacific rock crab (13%) (**Table 5-5**). Other shellfishes in impingement included shrimps, octopus, spiny lobster, and market squid. Unlike fishes that can be drawn into the intake when they are swimming in the water column, there are few free-swimming invertebrates. Most of the impingement of shellfishes probably occurs from organisms living within the CWIS. As a result there is very little potential for impingement of shellfishes and other invertebrates to affect source water populations of these species. For this reason the analysis in this report focuses on impingement of fishes.

The estimate of total annual impingement for fishes was computed using several methods to assess the potential of the reduced intake flow for the HBDF on impingement (**Table 5-3**). The standard approach for estimating total annual impingement uses a weighted average that uses the total flow during each survey period as the weights. In extrapolating the estimates for the HBDF, the weights varied due to the differences in the number of days within each survey period since the design flow of 152 mgd was used in all of the calculations. The totals based on weighted and unweighted averages were very close in value since the number of days within each survey period did not vary considerably through the year and was usually seven days in length. The relationship of impingement to flow was also used in extrapolating annual impingement totals. The resulting regression equations used in the extrapolation both assumed that impingement would be zero with no flow. The two estimates differed when the datum was included from a survey when over 70% of all the queenfish were impinged. The two estimates bracketed the estimates obtained using the weighted and unweighted averages.

There was no strong relationship between lower flows and lower impingement rates when a linear regression model was applied to the data (**Figures 5-3, 5-4, 5-5, and 5-6**). A zero-intercept nonlinear regression showed lower impingement at low flows. One of the reasons for the poor linear relationship between flow and impingement may be due to the design of the HBGS intake which includes a velocity cap for reducing impingement. Recent studies at the Scattergood Generating Station in Santa Monica Bay have shown that velocity caps have the potential to reduce impingement by 95% or greater (MBC et al. 2007). The results from those studies verified the results of earlier studies at HBGS done in 1979–1980 by a team of researchers from the University of Washington. This study, which was summarized in the HBGS Proposal for Information Collection, may be the most comprehensive evaluation of velocity cap effectiveness ever conducted. This study collected impingement and source water data on individual species and the results were reported in several University of Washington technical reports (Thomas et al. 1979, Johnson et al. 1979, Johnson et al. 1980, Thomas et al. 1980a, Thomas et al. 1980b, Thomas et al. 1980c) and in an IEEE journal (Thomas and Johnson 1980). Although the intake studies were not done at the lower intake flows proposed for the HBDF, the lower intake velocities may allow fishes to avoid impingement to even a greater degree which may explain the poor linear relationship between flow and impingement in the HBGS 2003–2004 data. This was indicated by some of the results from the testing done at reduced flow during the 1979–1980 velocity cap studies (Thomas et al. 1980c).

Comparison of impingement losses of juvenile and adult fishes with source water populations (as was done for larval fishes and target invertebrates) is not possible due to insufficient data on the source water populations for these species. Even estimating the costs of impingement losses is difficult due to a number of complicating factors, including the need for age-length relationships and mortality estimates to convert early life stage fishes into equivalent fishery-age adults. There is usually only fishery information available for only a few species since many of the species impinged are not targeted by commercial or recreational fisheries. For example, the original report on the HBGS IM&E study included a cost estimate of impingement that was based on 15 of 57 total fishes collected during both normal and heat treatment impingement sampling. An optional approach, which provides an extremely conservative estimate of the cost of the losses, is to assume that all of the biomass impinged is from a highly valued species such as California halibut. The estimated daily biomass of impinged fishes, excluding skates and rays, for the proposed HBDF intake of 152 mgd was 134 g (0.30 lb), or 49.0 kg (108 lb) annually. The average dollar value for California halibut for the recent period of 2004–2008 was $10.74 per kg ($4.87 per lb) resulting in a total estimate of $526 for the impingement losses.

6.4 Impact Summary

The proposed operation of the HBGS intake system for the HBDF would result in an estimated daily impingement of 13 fishes weighing a total of 0.3 kg (0.7 lb), equating to an annual estimated impingement of 4,853 fishes weighing 117.6 kg (259 lb). Several approaches were used for estimating the results which indicated that the average daily totals could vary from 7 to 22 fish, resulting in an annual total of approximately 2,500 to 8,000 fishes. A nonlinear model showed that daily impingement could be as low as 0.5 fish at intake flow of 152 mgd. The existing data and results from previous studies on the effectiveness of the intake velocity cap (Thomas et al. 1980c) indicate that impingement may be lower at the low flows projected for the HBDF than would be predicted based on the proportional relationship of impingement to flow.

The data from the 2003–2004 study showed that queenfish was the most abundant species in impingement samples by a large margin, comprising over 80% of the estimated annual impingement. Although there were no source population estimates available for impinged species with which to determine if the losses were "substantial" on a population level, an extremely conservative assumption that all of the impinged biomass excluding skates and rays was equivalent to California halibut was used to estimate the total annual cost of the losses at $526. The low value of the total impingement even using these very conservative assumptions and the fact that there were no state or federal threatened or endangered species collected during the impingement sampling indicates that the impacts of impingement under HBDF operations would not be significant.

Impacts to fish and invertebrate populations caused by the entrainment of planktonic larvae through the proposed HBDF intake can only be assessed indirectly through modeling. These impacts are additive with the direct impingement losses. Of the ten abundant fish species entrained at HBGS, seven have some commercial or recreational fishery value. The *ETM* procedure estimates the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The P_M estimates for all of the target taxa were all less than 0.33% (**Table 6-1**). The alongshore estimates indicate that these impacts occur over an estimated 18–100 km (11–60 mi) of coastline. The distance of shoreline potentially affected is directly proportional to the estimate of time that the larvae are exposed to entrainment. Less than half of the 53 different fish taxa entrained belonged to species with some direct fishery value (e.g., sand basses, white seabass, California barracuda) and most of those were occurred very infrequently in the samples. Because of their low abundance in the samples, most of these taxa were not modeled for potential impacts. The single invertebrate taxon modeled for entrainment impacts, cancrid crabs, had projected impacts of 0.33% of a source water population extrapolated along a shoreline distance of 100 km (60 mi). Even in a heavily exploited commercial species these levels of additional mortality would be considered very low, especially when the populations of these species extend over a much larger geographic range than the extrapolated source water bodies. This and the fact that there were no state or federal threatened or endangered species collected during the entrainment sampling indicates that the impacts of entrainment under HBDF operations would not be significant.

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